DOE/NASA CONTRACTOR REPORT

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SOLAR HEATING AND COOLING SYSTEM INSTALLED AT COLUMBUS, OHIO -- FINAL REPORT

Prepared from documents furnished by

Columbus Technical Institute
550 E. Spring Street
Columbus, Ohio 43216

Under DOE Contract EG-77-A-01-4090

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National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

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U.S. Department of Energy

Solar Energy

UDR-TR-80-58

COLUMBUS TECHNICAL INSTITUTE
SOLAR HEATING/COOLING DEMONSTRATION PROJECT

Final Report

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September 1980

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Prepared for the

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16. ABSTRACT

This document is the Final Technical Report of the Solar Energy System installed at Columbus Technical Institute, Columbus, Ohio. The Solar Energy System was installed as a part of a new construction of a college building. The building will house classrooms and laboratories, administrative offices and three lecture halls. The Solar Energy System consists of 4,096 square feet (128 panels) Owens/Illinois Evacuated Glass Tube Collector Subsystem, and a 5,000 gallon steel tank below ground storage system, hot water is circulated between the collectors and storage tank, passing through a water/lithium bromide absorption chiller to cool the building.

This report includes extracts from the site files specification references, drawings, installation, operation and maintenance instructions.

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PREFACE

The efforts reported herein were conducted by a project team assembled by the Columbus Technical Institute under the Department of Energy, Solar Heating and Cooling Demonstration Project for Nonresidential Buildings, Cooperative Agreement No. EG-77A 014090. This work, sponsored by the Department of Energy (DOE), was managed by the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center, Huntsville, Alabama. The NASA manager is Mr. Douglas W. Westrope. This report covers work conducted during the period July 1976 through May 1980.

The authors, Mssrs. Richard G. Coy and R. Paul Braden, University of Dayton Research Institute, would like to acknowledge the cooperation and contributions of all of the project team whose members are: Columbus Technical Institute, Project Director, Mr. Russell Jordan; McDonald, Cassell & Bassett, architects, Mr. William R. McDonald; Lantz & Jones, structural consultants, Mr. James Nebraska; Heapy & Associates, Mr. Richard Pearson; University of Dayton Research Institute, solar system design consultants, Dr. J. E. Minardi, Mr. R. K. Newman, Mr. D. H. Whitford, and Mr. G. J. Roth; Owens-Illinois, Inc., solar collector manufacturers, Mr. V. R. Daiga and Mr. R. E. Ford; and Elford, Inc., general contractors, Mr. Tom Fitzpatrick.

SECTION 1
INTRODUCTION AND SUMMARY

In May 1977 the Columbus Technical Institute (CTI), 550 East Spring Street, Columbus, Ohio 43216, was selected as a recipient of a nonresidential solar energy demonstration contract awarded by the Department of Energy (DOE), in response to Program Opportunity Notice DSE-76-2. CTI proposed to include a solar energy heating/cooling system in its new classroom/administration building, designated as the "Phase V Building", which was approved for construction in 1976 by the Ohio General Assembly.

The Phase V Building (Franklin Hall) was built in the northeast quadrant of the CTI campus on land owned by the college, five blocks east of the Ohio State capital building. It has approximately 47,000 square feet of floor space on three levels. The solar heating and cooling system designed for the building utilizes about 4,096 square feet of advanced, evacuated, tubular collectors located on the roof. The collectors were built by the Owens-Illinois Company.

The overall program was managed by the National Aeronautics and Space Administration (NASA), Marshall Space Flight Center, Huntsville, Alabama, for DOE. The efforts discussed in this report were conducted by a project team, whose members are: Mr. Russell Jordan, Administrative Assistant to the CTI President; McDonald, Cassell & Bassett, architects; Lantz & Jones, structural consultants; Heapy and Associates, mechanical engineering consultants; University of Dayton Research Institute (UDRI), solar system design consultants; Owens-Illinois, solar collector manufacturer; Elford, Inc., general contractor; and Duckworth Plumbing Co., mechanical contractor. Major subcontractors include: Honeywell, Inc. - control subsystem; and Remtech Inc. - data acquisition subsystem.

An overview of the campus and pictures of the completed building are shown as Figures 1-1, 1-2, and 1-3. The system was acceptance tested and became operational in June 1979. Performance

data is being collected by the Solar Data Acquisition and Reduction (SDAR) System provided by CTI.

COLUMBUS TECHNICAL INSTITUTE

A - Eibling Hall
B - Administration Building
C - Rhodes Hall
D - Acquinas Hall
E - Educational Resource Center
F - Health and Academic Facility
G - Business and Automotive Facility
H - Franklin Hall

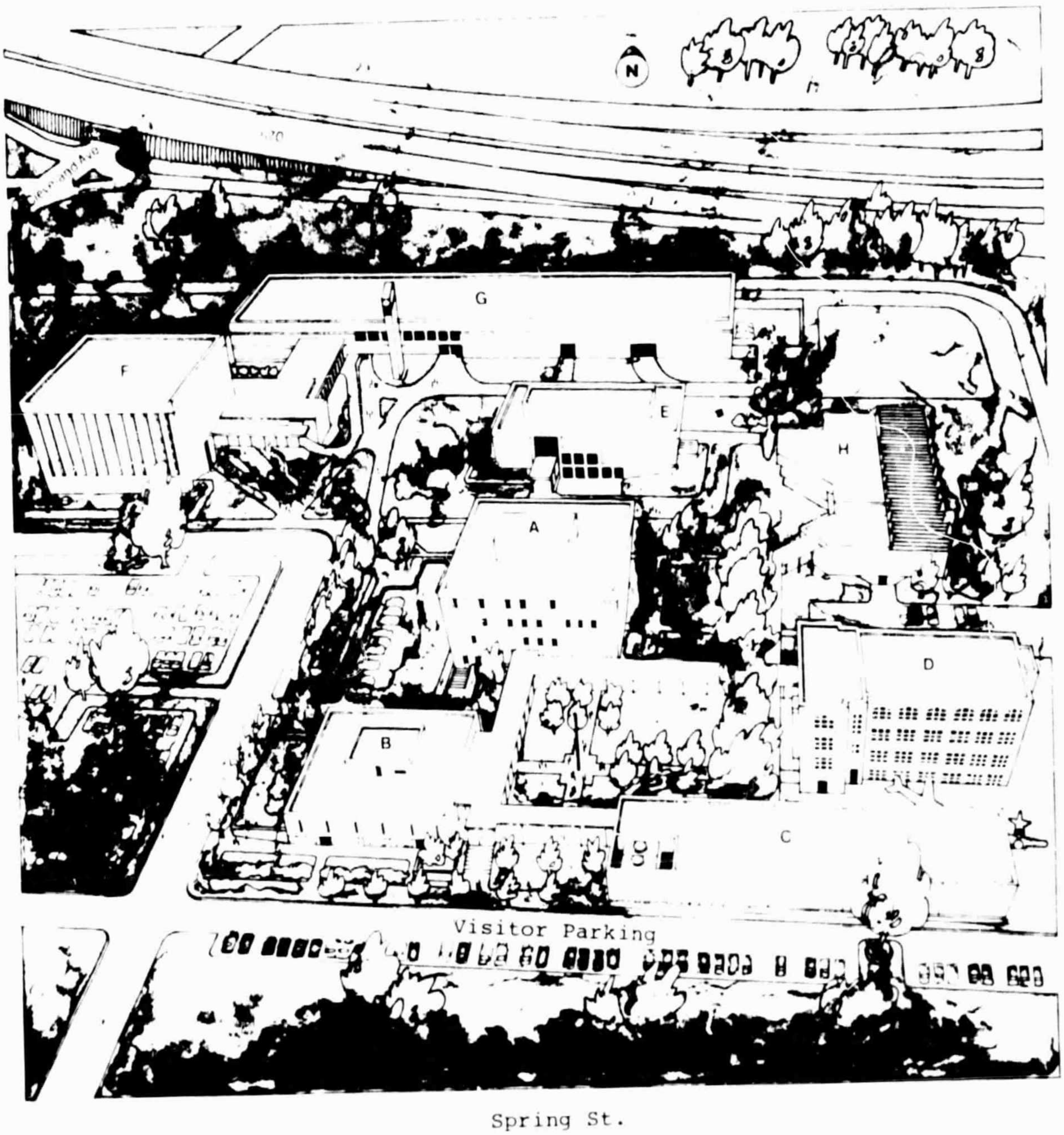


Figure 1-1. Columbus Technical Institute. (Courtesy CTI)

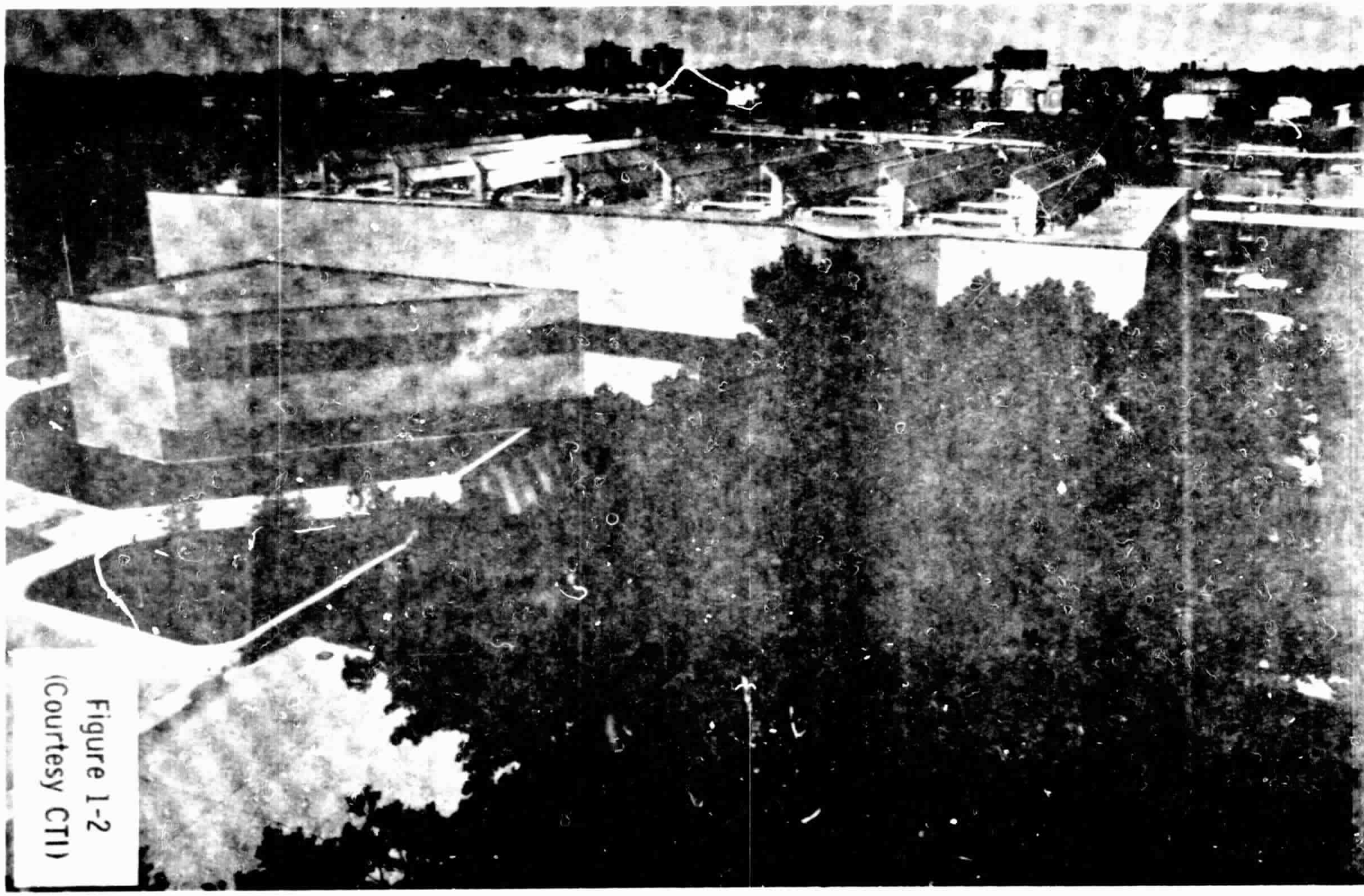


Figure 1 2. Aerial View of Franklin Hall.

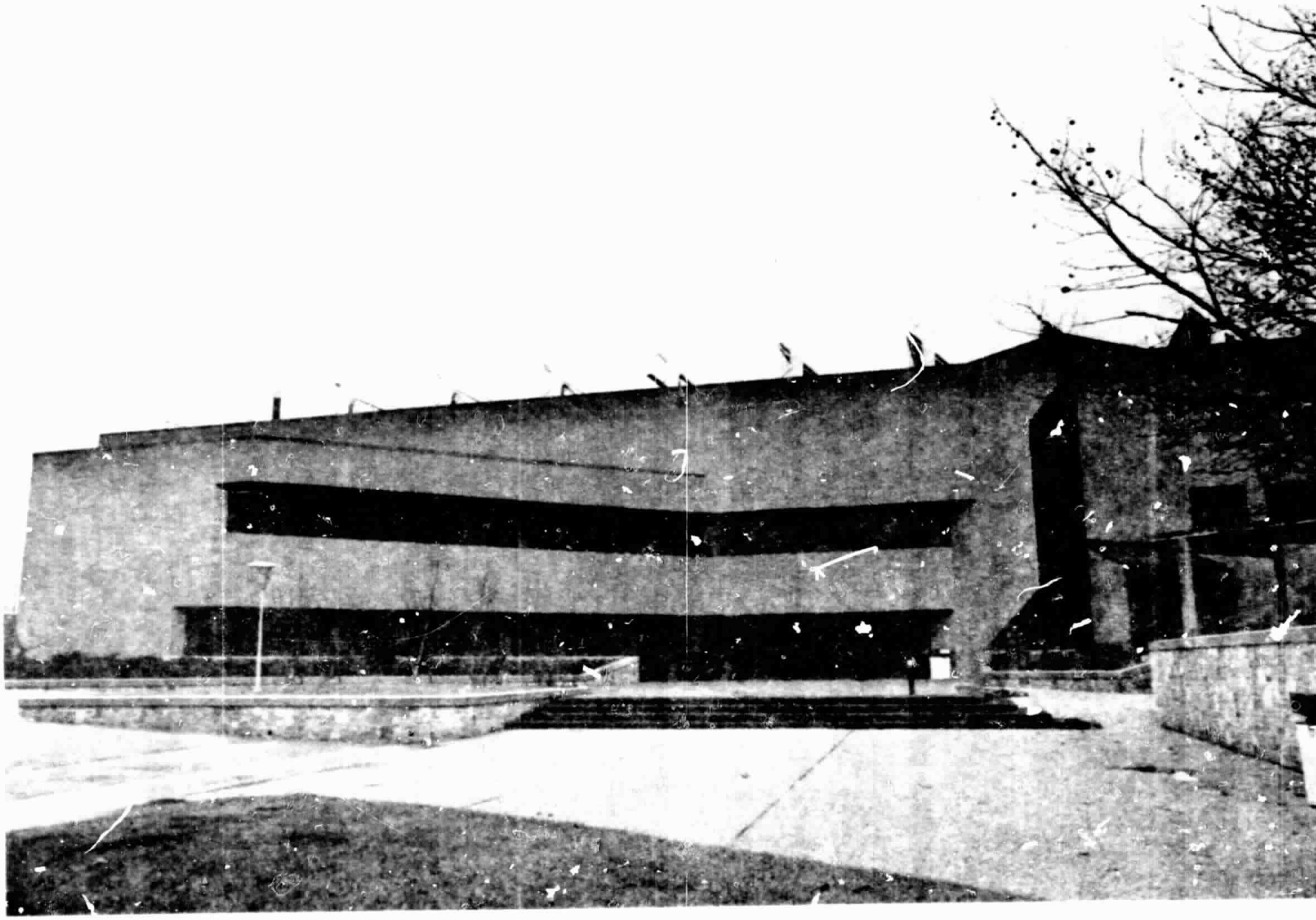


Figure 1-3. Ground View of Franklin Hall.
(Courtesy CTI)

SECTION 2

SITE AND SYSTEM DESCRIPTION

Franklin Hall of the Columbus Technical Institute is located in downtown Columbus, Ohio, at 40° North Latitude and 83° West Longitude (See Figure 2-1). The collectors, which face due South, are mounted at an angle of 45° measured from the horizontal.

The maximum number of solar collectors that could be mounted on the roof were used in the solar heating system. They should provide 79 percent of the total annual heating requirements of the building and 27 percent of the annual cooling (through absorption chilling). Each collector is 4 ft wide and 8 ft high. The collectors are arranged in 8 rows, 16 collectors per row. All pipe connections to the collectors are made through vertical chutes "or roof curbs" which penetrate the poured asphalt roof.

The collectors are identical to those installed in the Troy, Ohio Library earlier (reference DOE report UDR-TR-80-14, February 1980). They are normally nondrainable, but can be manually drained by partial disassembly if an emergency occurs, such as a catastrophic circulation pump failure during the periods of extremely low temperature and minimum sunlight. They are not drained in summer; hot water is circulated between the collectors and an insulated 5,000 gallon holding tank, passing through a water/lithium bromide absorption chiller to cool the building. If the solar collector temperature goes above 220°F, solar heat is dissipated through heat exchangers into the cooling tower which services the chiller system. In event of a building power failure, a manual valve allows city water to be used for emergency collector cooling.

The CTI solar heat/cooling system includes multiple modes of operation:

1. HEATING ONLY

a. Solar collectors provide sufficient heat to meet the demand (See Figure 2-2).

Figure 2-1. Location of Columbus, Ohio.

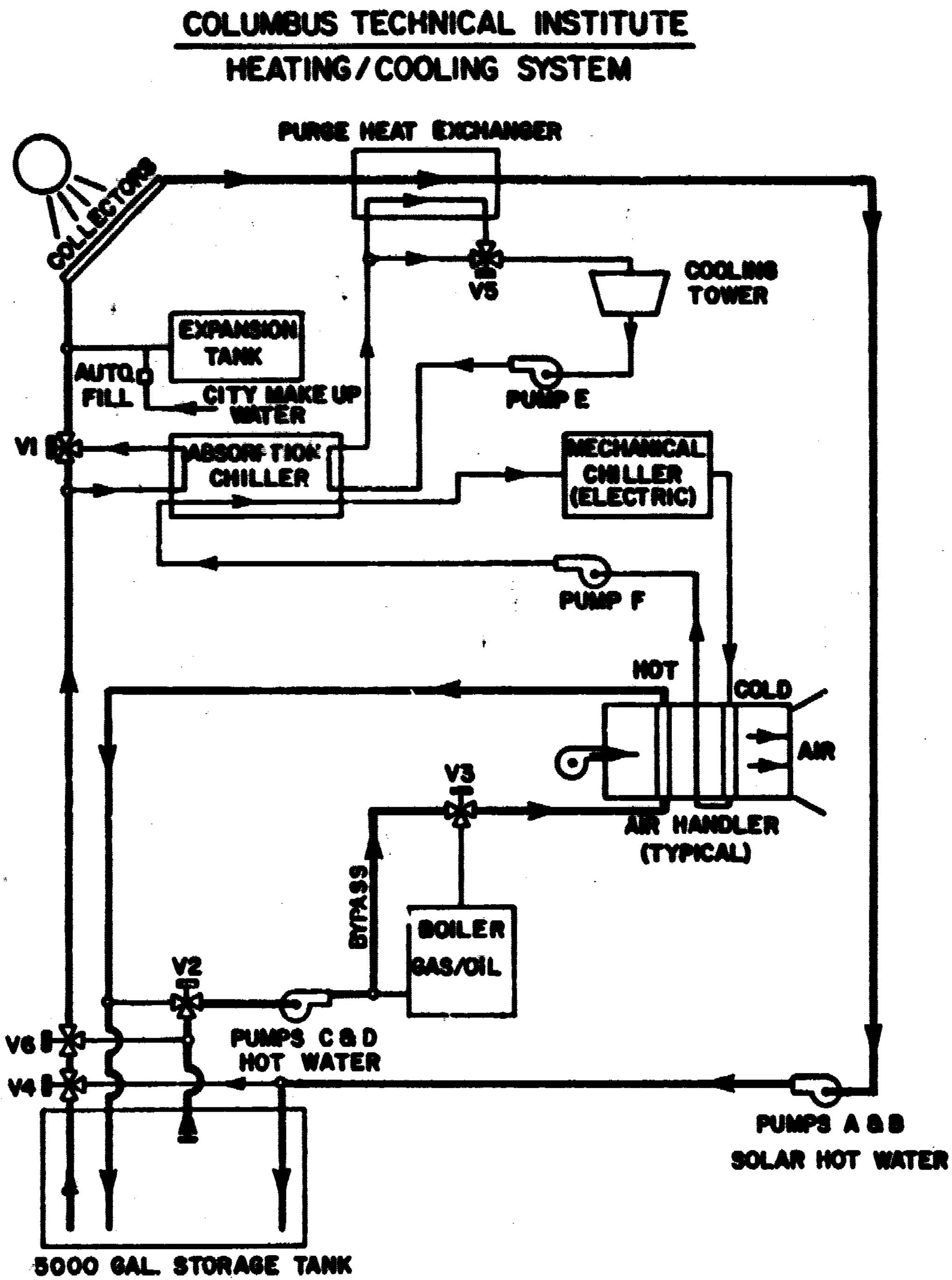


Figure 2-2. Schematic, Heating Mode.
(Courtesy Heapy & Associates)

b. Supplementary heating is necessary (see Figure 2-3). To keep the boiler from supplying heat to the storage tank, valve V2 activates to allow the return water from the air handlers to return directly to the boiler, by-passing the storage tank. (Only the solar collectors put heat into the storage tank.) As soon as the solar collectors heat the storage tank to a temperature greater than the air handler return water temperature, valve V2 allows tank water to enter the boiler.

2. COOLING ONLY

a. So long as the storage tank water temperature remains between 170 and 220°F, Figure 2-4 applies. If the temperature drops below 170°F, the absorption chiller cannot operate. It goes off line and valve V1 opens to bypass the chiller. All chilling is accomplished by reciprocating chillers in series with the absorption machine. (This mode is not shown on a separate figure.)

b. When the solar collector water temperature rises above 220°F, the excess heat is dumped into the Purge Heat Exchanger and Cooling Tower, as shown on Figure 2-5.

3. MIXED MODES

Individual air handlers have the capability of calling for heating or cooling individually, so mixed modes are possible.

4. OVERHEAT AND FREEZE PROTECTION MODES

The control logic for the solar heating/cooling system has built-in protection against overheat or freezing of the solar collectors, independent of the demand for heat or cold by the air handlers (see Appendix C, Honeywell Control System Drawings, sheet 5 of 10). They include:

- Collector overtemperature--If the collector discharge temperature exceeds 220 to 230°F, the cooling tower loop (pump E, purge heat exchanger and cooling tower, Figure 2-5) activates to reduce the discharge temperature below 220°F.

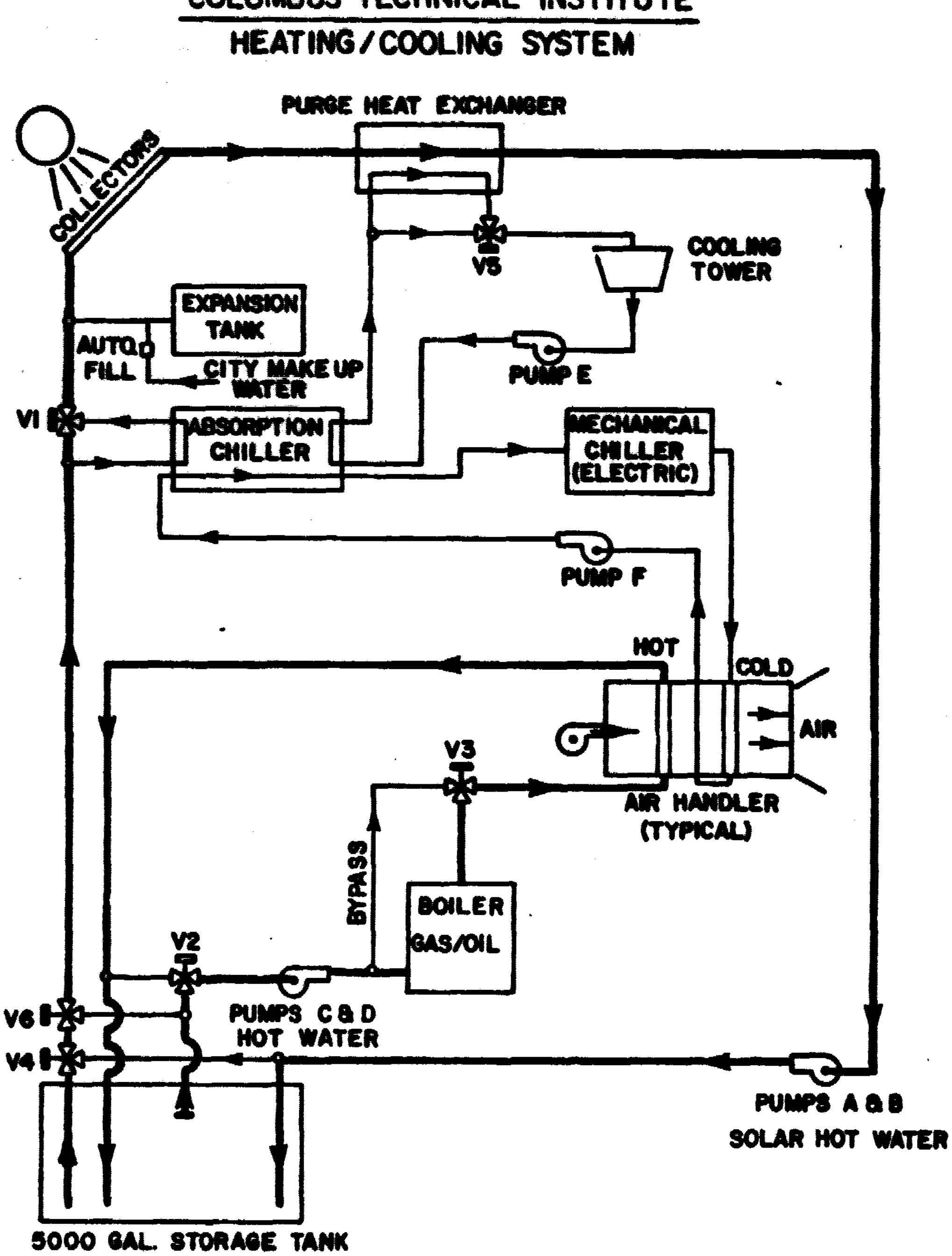
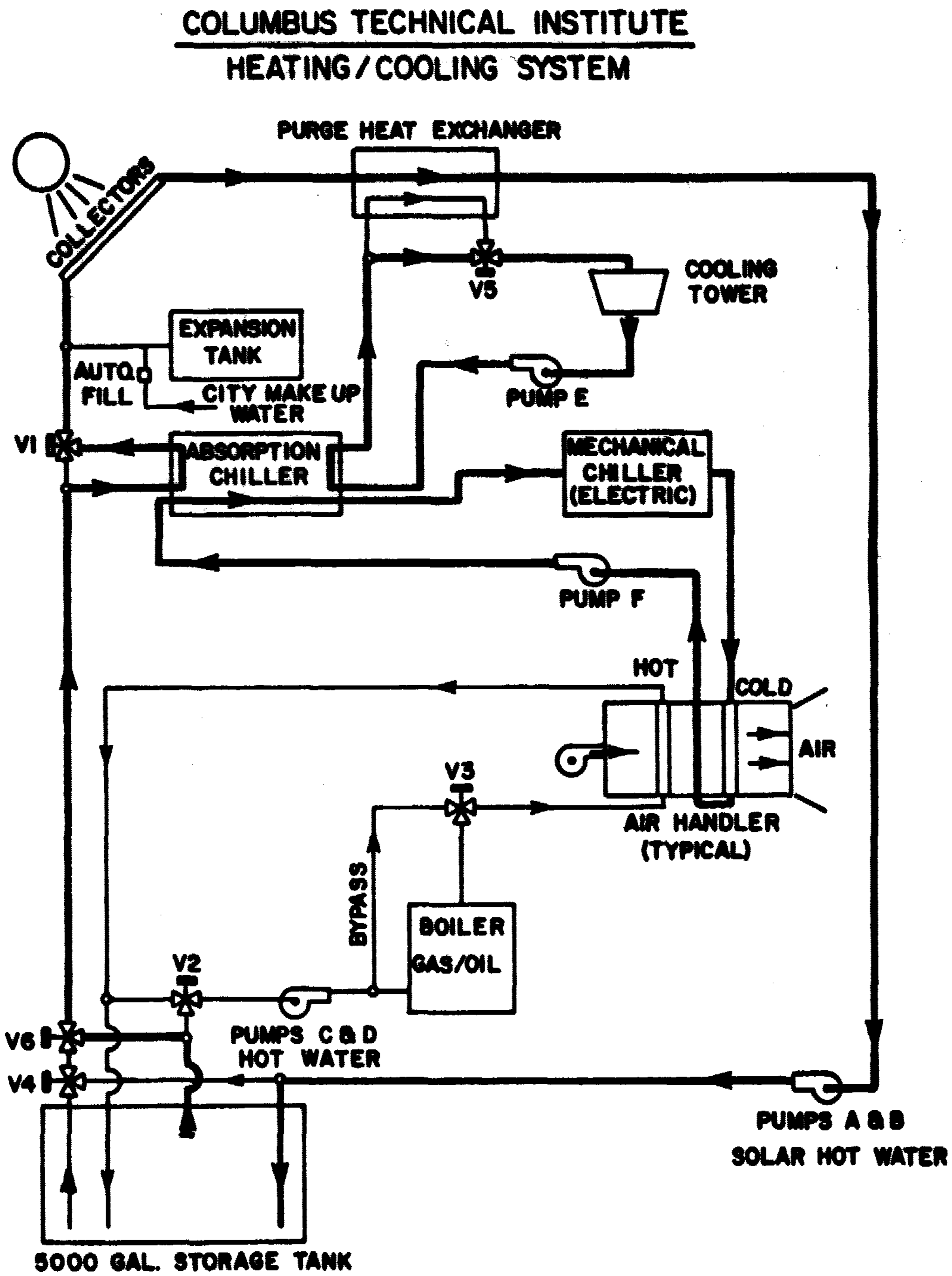
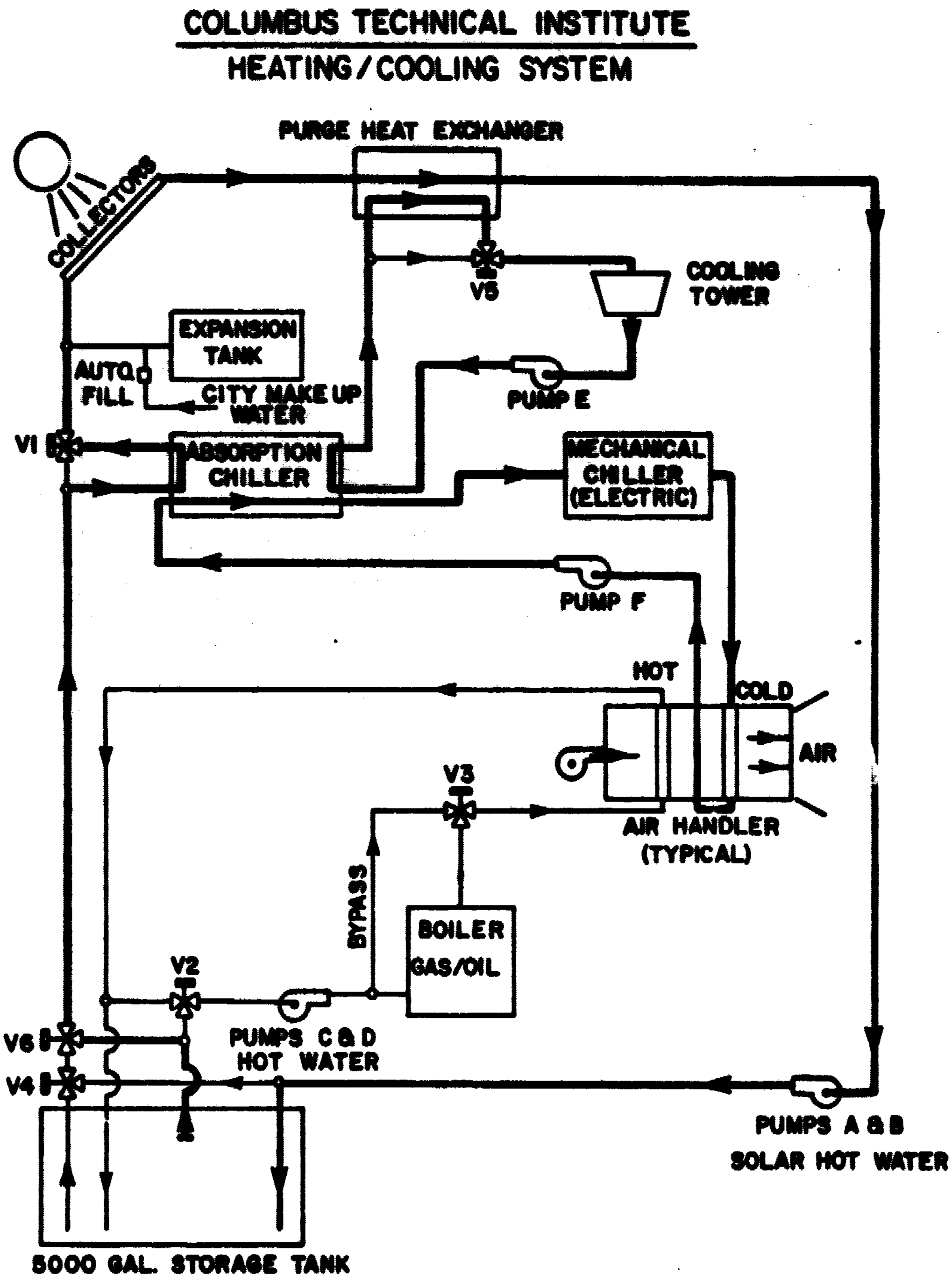


Figure 2-3. Schematic, Heating Mode, Extreme Cold. (Courtesy Heapy & Associates).



(SOLAR COLLECTOR WATER TEMPERATURE BETWEEN 170° AND 220° F)

Figure 2-4. Schematic, Cooling Mode, Low Collector Temperature. (Courtesy Heapy & Associates)



(SOLAR COLLECTOR WATER TEMPERATURE EXCEEDS 220°F)

Figure 2-5. Schematic, Cooling Mode, High Collector Temperature. (Courtesy Heapy & Associates)

● Collector freeze protection--If the outside air temperature drops below 40°F, pumps A and B cycle on for one-half hour every four hours. If the collector discharge temperature drops below 40°F, valve V4 is positioned such that pumps A and B (Figure 2-3) pump water continuously through the collectors from the storage tank until the discharge temperature reaches 60°F. Since the control system does not permit the boiler to provide heat to the storage tank, the heat necessary to raise the collector temperature must come from the storage tank and its surroundings. If the collector discharge temperature continues to drop (to 38°F or less) a remote bell in Aquinas Hall rings until the condition is corrected. Maintenance personnel must open valves to introduce city water into the collector water loop to raise its temperature above 40°F.

5. EMERGENCY MODES

If water circulation through the solar collectors is interrupted for periods greater than 30 minutes or so when solar insolation is high, overheat will occur; the water trapped in the collectors will turn to steam, and escape from pressure relief valves at the outlet of each collector row (see Figure 3-1, page 28, and Section 3.2, page 29). To control the rate of steam release and decrease the collector temperature, it is necessary to cover the collectors with black Visqueen, and keep them covered until the water circulation problem is corrected. This emergency condition has already occurred in the Franklin Hall System, and was handled well by maintenance personnel.

If water circulation stops and there is no solar insolation (heavy cloud conditions and arctic-type cold), the collectors must be manually drained, per Section 3.2, page 29.

2.1 SOLAR COLLECTOR SUBSYSTEM

One-hundred-twenty-eight SUNPAK™ solar collector modules with shaped reflectors are installed on this project. These collectors are advanced, high performance, evacuated, tubular collectors manufactured by Owens-Illinois, Inc. Each module

consists of 24 individual collector tubes with an integral manifold as shown in Figure 2-6 through 2-10 and occupies approximately 32 square feet in the assembled configuration. The effective area of the standard SUNPAK™ module is 27.4 square feet, which is used as the basis for describing collector performance. The effective collector area available on this project with 128 modules is 3507 square feet. A complete description of the Owens-Illinois, Inc. collector is presented in Appendix B, SUNPAK™ Solar Collector Installation Service and Operating Manual.

2.2 STORAGE SUBSYSTEM

The capability of storing excess solar energy is provided by an insulated 5,000 gallon steel tank. The tank is installed below ground, adjacent to the northwest corner of the building. Construction and installation details of the tank are shown in Appendix A.

2.3 DISTRIBUTION AND CONTROL SUBSYSTEM

This subsystem includes all piping, pumping, and heat transfer components as well as the required control logic for the efficient operation of the entire system. The system schematic presented in Figure 2-11 shows all major components of the distribution subsystem as well as the control valves and sensors. All piping in the distribution system is installed within the building.

The pneumatic control subsystem was designed and built by Honeywell, Inc. It meets the demand for heat in a given sector of the building by first using the energy in the storage tank and collector system, then calling for back-up heat from the natural gas/oil boiler. Details of the control subsystem are shown in Appendix C.

Six three-way pneumatic valves control the flow of water within the solar system. They are shown on Figure 2-11 as V1

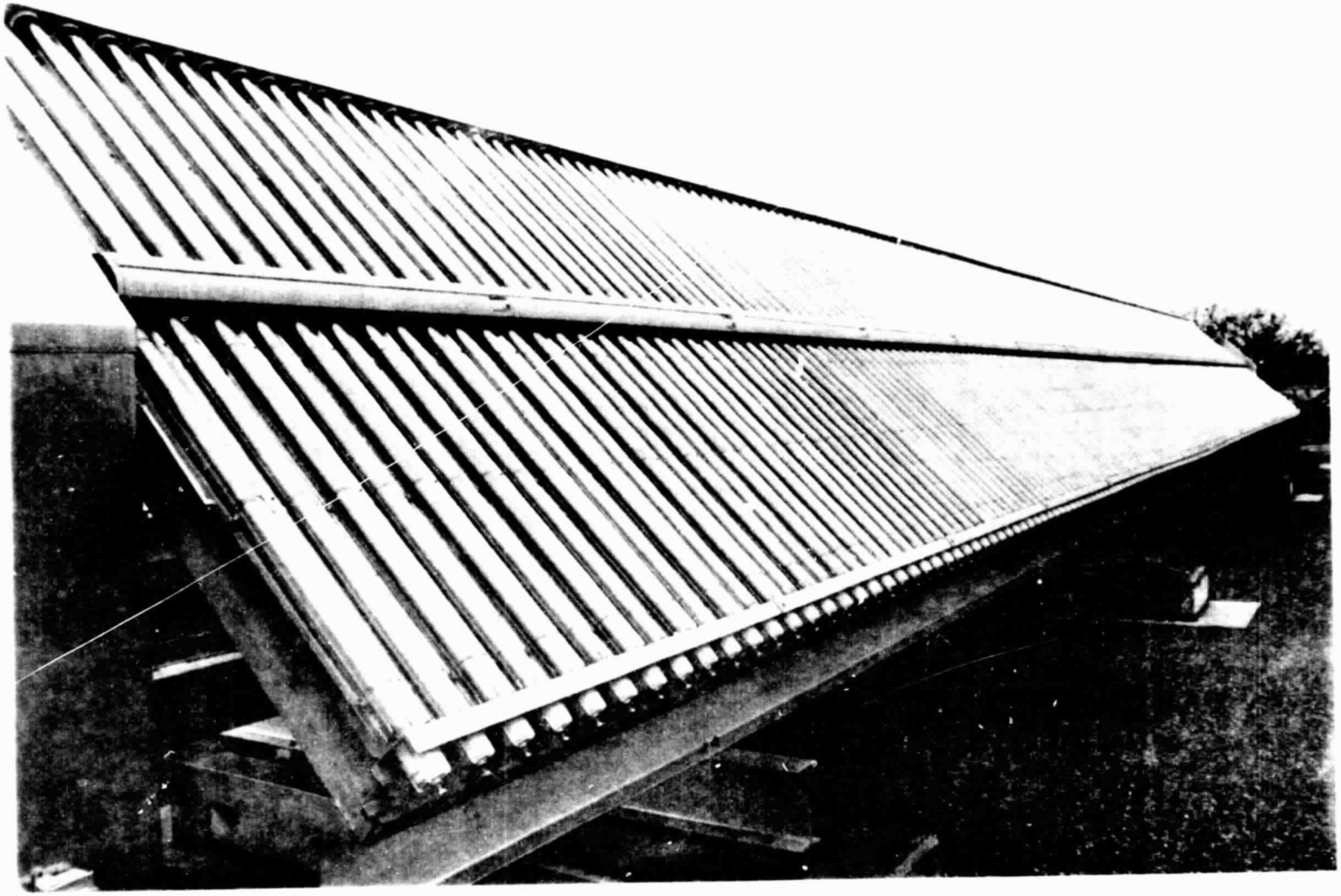


Figure 2-6. CTI Collectors on Roof.
(Courtesy CTI)

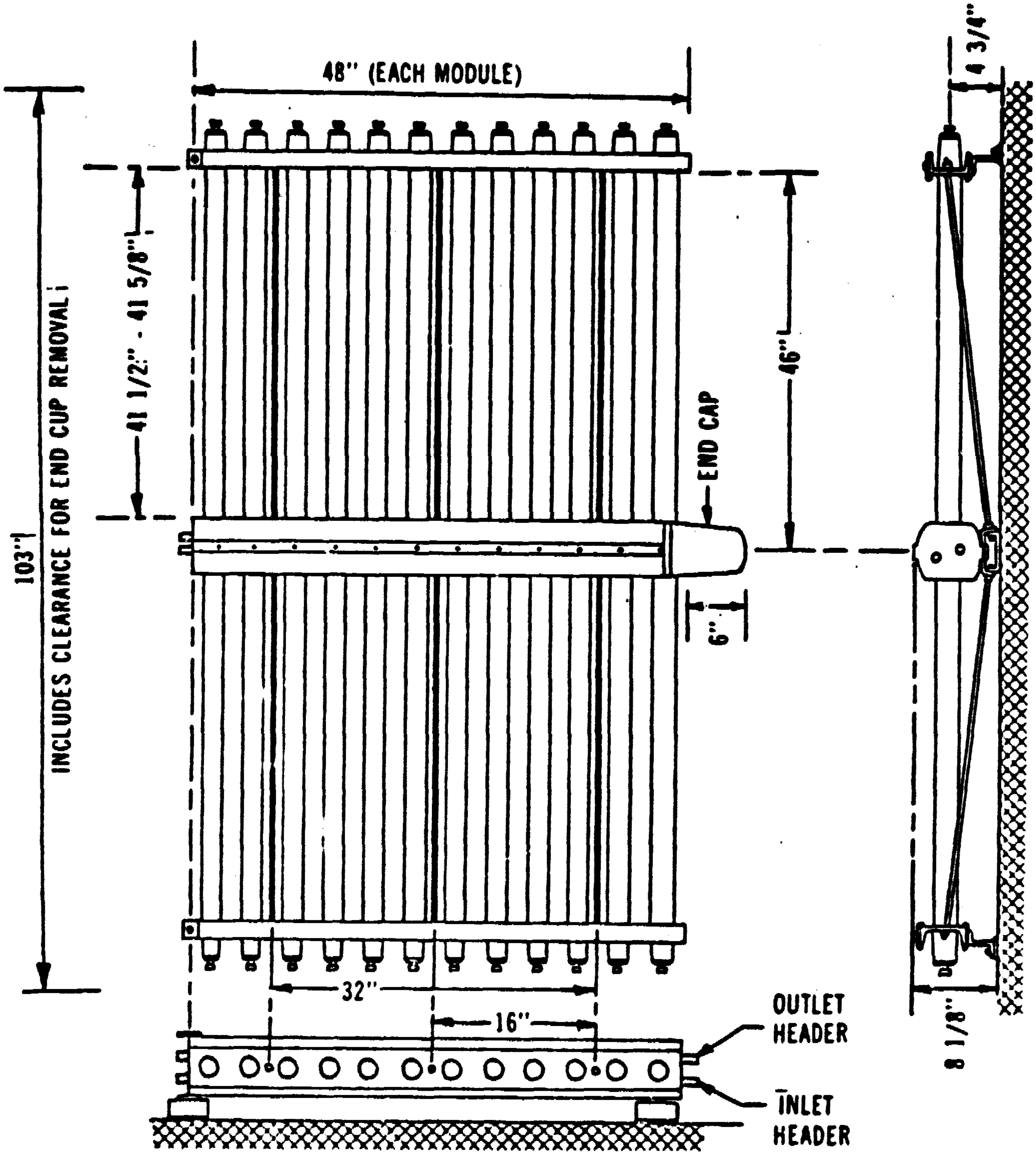


Figure 2-7. SUNPAK™ COLLECTOR PICTORIAL.
(Courtesy Owens-Illinois)

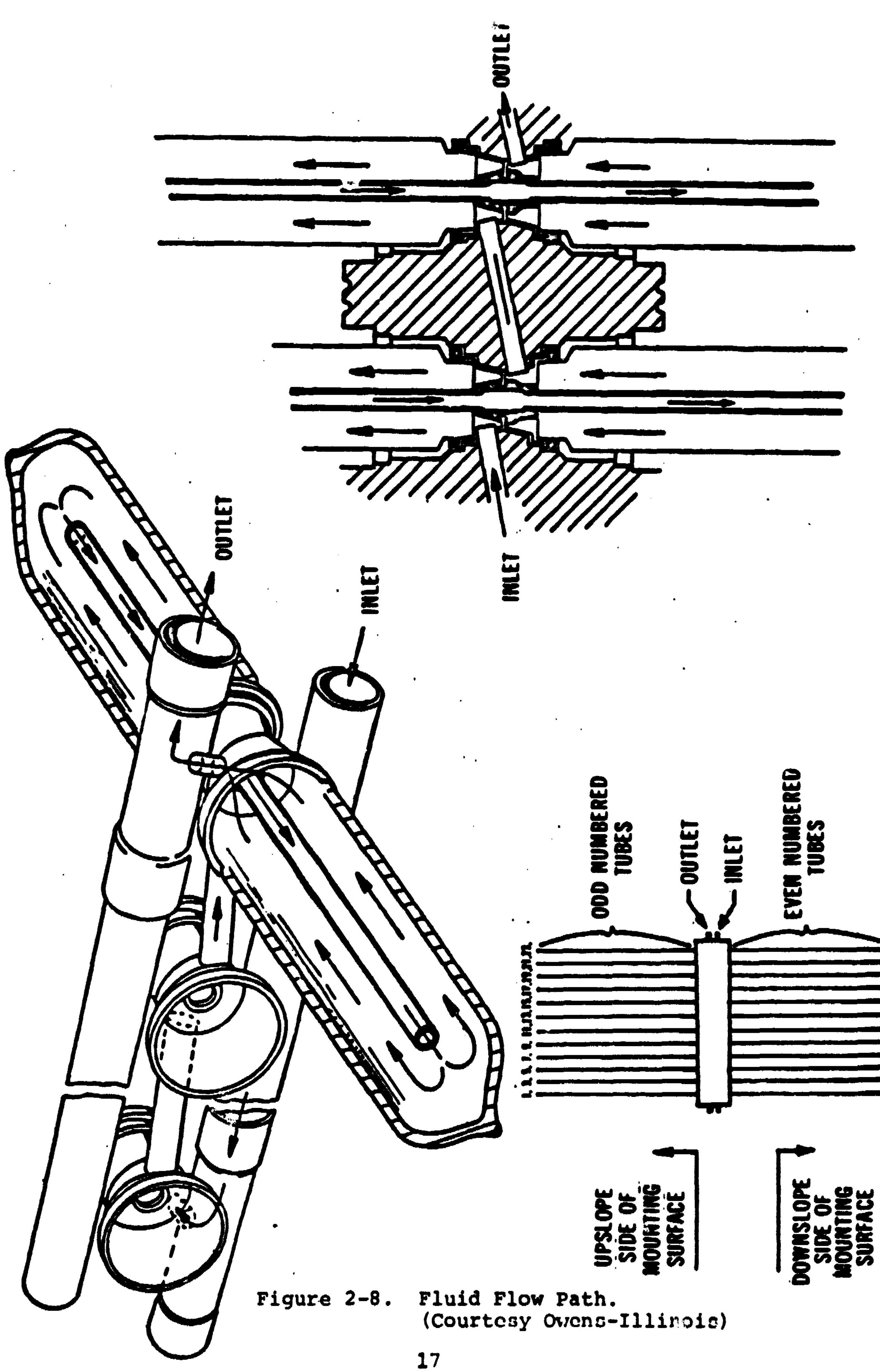


Figure 2-8. Fluid Flow Path.
(Courtesy Owens-Illinois)

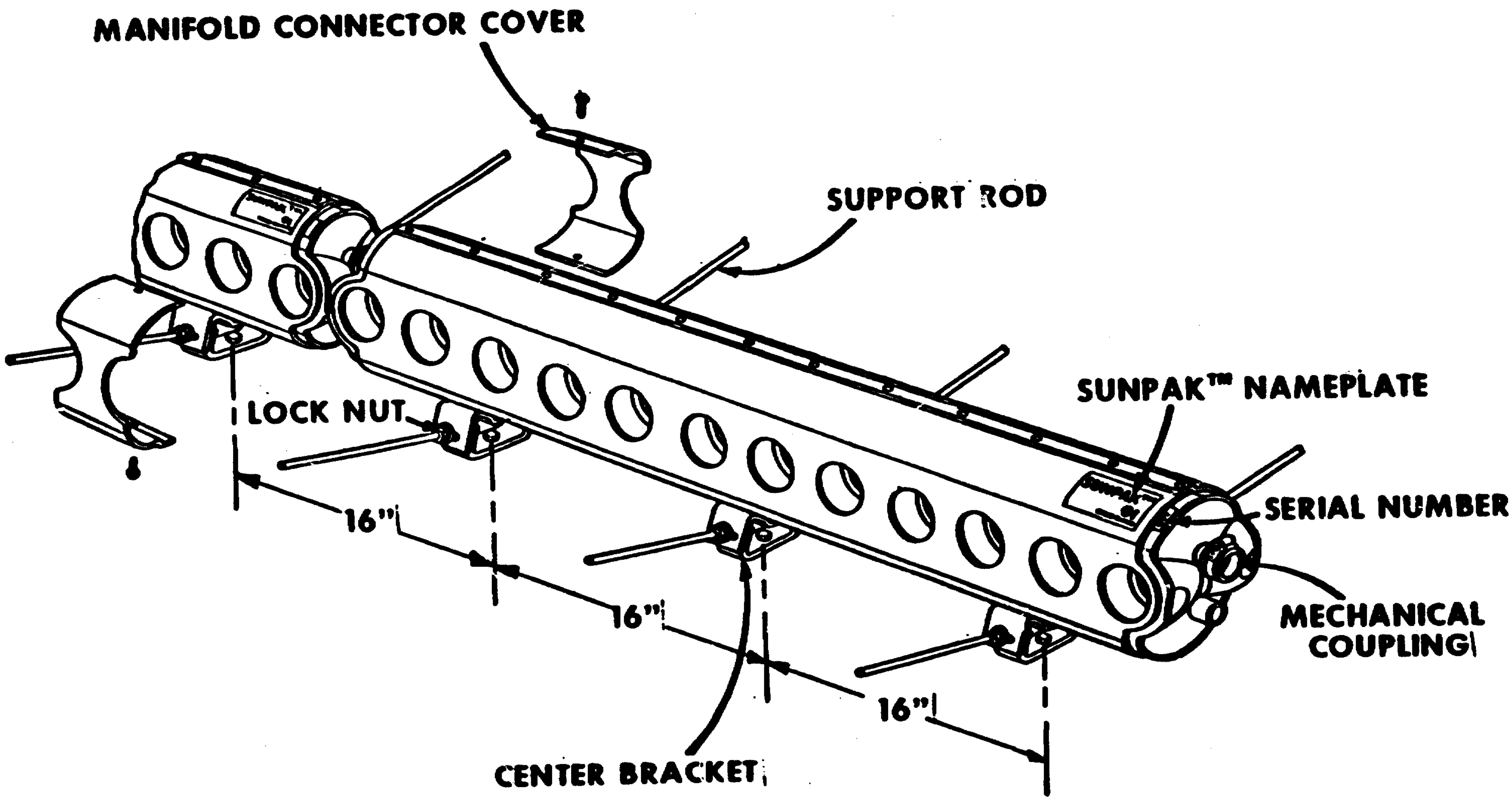


Figure 2-9. Manifold Assembly.
(Courtesy Owens-Illinois)

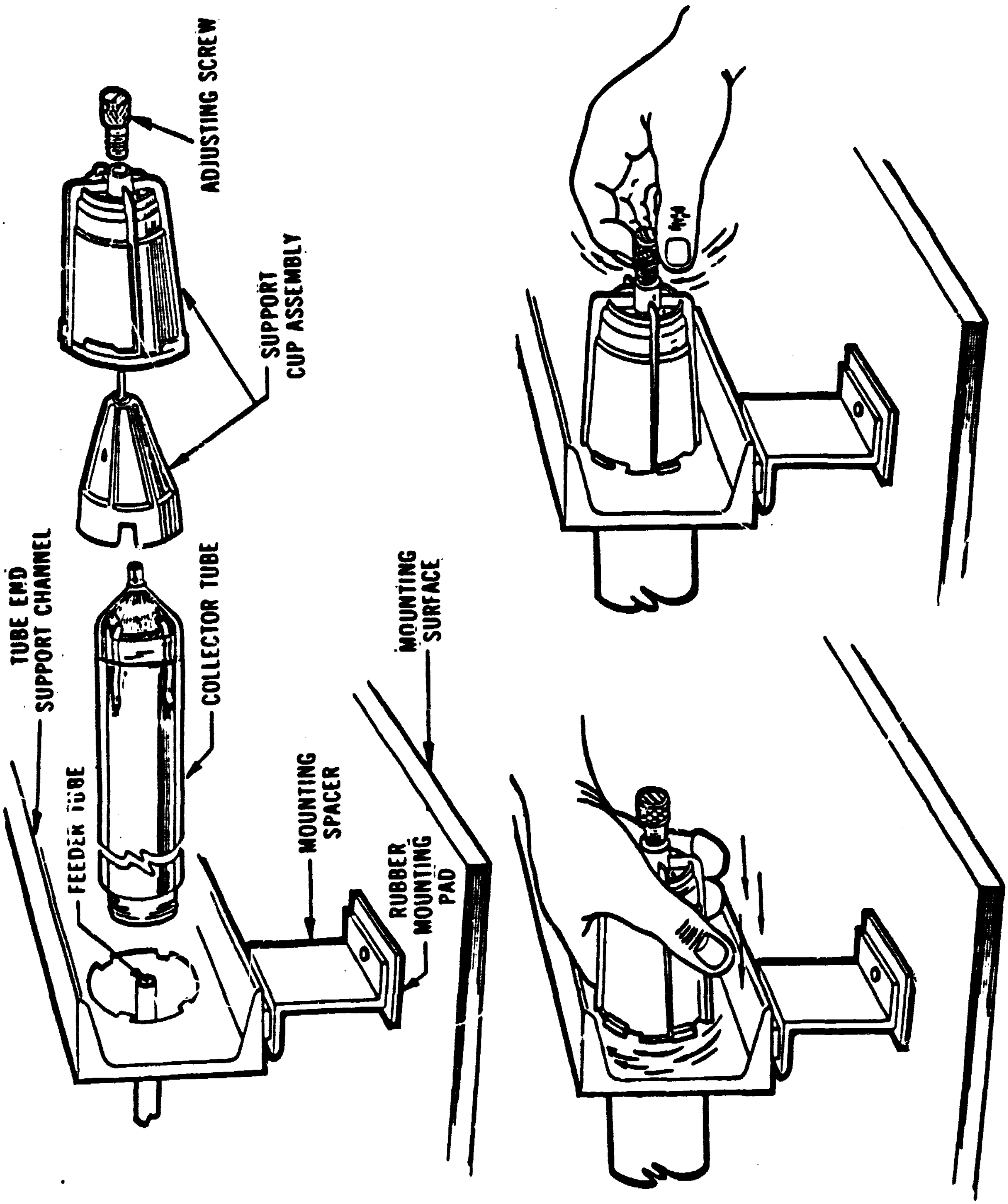


Figure 2-10. Collector Tube Installation.
(Courtesy Owens-Illinois)

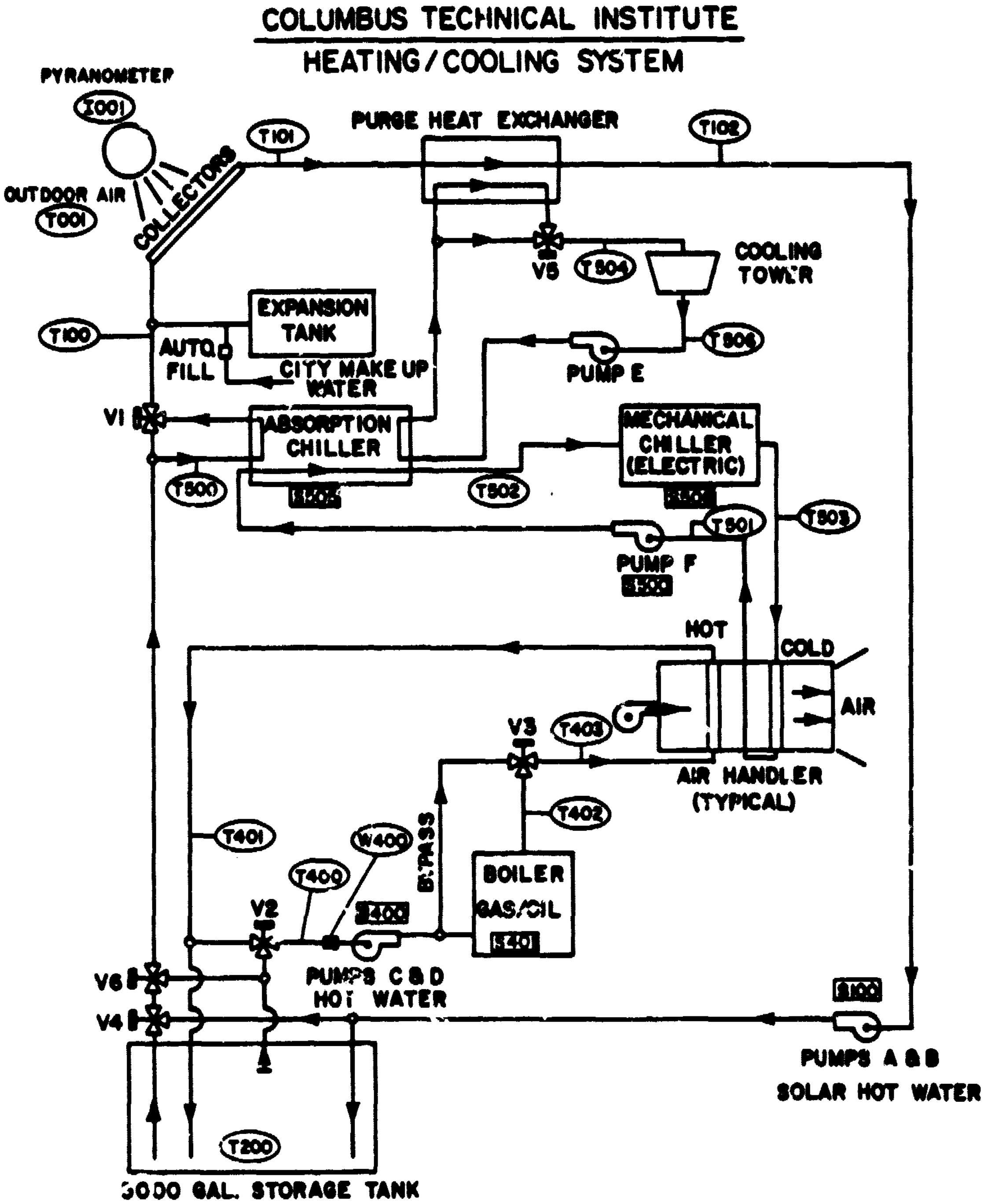


Figure 2-11. Major System Parameters & Control Valves. (Courtesy Heapy & Associates)

through V6. Their functions are:

1. V1 - Bypass the absorption chiller when no cooling is required.

2. V2 - Bypass the storage tank if the return water temperature from the air handlers is greater than the storage tank temperature.

3. V3 - Bypass boiler unless air handler hot water loop temperature is too low to heat the building.

4. V4 - Bypass storage tank if tank temperature is greater than water temperature in the solar collectors.

5. V5 - Bypass the purge heat exchanger because water temperature is below 220°F. (The cooling tower is a component of the building cooling system, and is used by the solar system only when the solar hot water temperature is excessive).

6. V6 - Allow hot water to be drawn from the top of the storage tank when in the cooling mode.

2.4 DATA COLLECTION AND LOBBY DISPLAY INSTRUMENTATION

The Franklin Hall solar heating system is equipped with minimum instrumentation to assess the overall performance of the system. This instrumentation was purchased by CTI under private contract in 1977.

The Solar Data Acquisition and Reduction (SDAR) system was built by Remtech, Inc., of Huntsville, Alabama, for the CTI installation, with the cooperation of Heapy and Associates. The system is built around a Digital Equipment Corporation LSI #11/2 general-purpose 16-bit microcomputer processor module. The system will interrogate up to 32 analog inputs, convert them to engineering units, calculate heat flows through the system, display the results on a video monitor (mounted in the lobby and provided on-demand), and record the system parameters on a cassette tape.

The data is also retrievable remotely via telephone modem. The inputs to the system are shown as Figure 2-12, the required solar system constants as Figure 2-13, and the system performance calculations as Figure 2-14.

A sample lobby terminal display is shown as Figure 2-15. Details on SDAR are shown in Appendix D.

Channel	Sensor	Variable	Function
1	I1	I001	Incident solar energy
2	T15	T001	Outdoor air temperature
3	T6	T100	Collector inlet/Absorbtion chiller outlet
4	T1	T101	Collector outlet/Purge inlet
5	T12	T102	Purge outlet
6	R1	S100	Collector pump status
7	T2	T200	Storage tank temperature
8	T7	T400	Storage outlet/Boiler inlet
9	T3	T401	Heating loop return
10	T8	1402	Boiler outlet
11	T4	T403	Heating loop supply
12	R2	S400	Heating loop pump status
13	R3	S401	Boiler status
14	FM1	W400	Heating loop flow rate
15	T11	T500	Absorbtion chiller inlet
16	T14	T501	Cooling loop return/Absorbtion chiller load inlet
17	T9	T502	Absorbtion chiller load outlet/Electric chiller inlet
18	T10	T503	Cooling loop supply/Electric chiller load outlet
19	T13	T504	Cooling tower inlet
20	T5	T506	Cooling tower outlet
21	R4	S500	Cooling loop pump status
22	R5	S505	Absorbtion chiller status
23	R6	S506	Electric chiller status

Figure 2-12. Input Channel Assignments.
(September 1979)
(Courtesy Remtech)

AREA - Collector area -(3507.2 sq. ft.)
W100 - Collector loop flow rate -(60 GPM)
EP101 - Collector pump operating energy -(11.5 KW)
W400 - Flowmeter conversion data -(1 pulse/10 gal 350 max - 100 min)
EP400 - Heating loop pump operating energy -(31 KW)
W500 - Cooling loop flow rate -(300 GPM)
EP500 - Cooling loop pump operating energy -(15.5 KW)
EP504 - Cooling tower operating energy used by absorption chiller -(3.46 KW)
EP505 - Absorption chiller operating energy -(3.8KW)
W505 - Absorption chiller load flow rate -(1606 GMP)
W506 - Electric chiller load flow rate - (3006 GPM)
HTCOST - Cost per Btu of conventional heating-($7.49/1 x 10^6BTU)
CLCOST - Cost per But of conventional cooling-($2.00/1 x 10^6BTU)
MININ - Insolation required for useful solar collection -(20 BTU/sq.ft.)

* Data in ( ) are the constants in program supplied on September 1979. These constants may be changed by the use of Task 4 in the SDAR System Task List.

Figure 2-13. Required Solar System Constants. (Courtesy Remtech)

Solar energy available:	$Q001=\int I001\cdot AREA\cdot dt$
Solar energy collected:	$Q100=\int (T101-T100)\cdot W100\cdot S100\cdot dt$
Solar energy purged:	$Q101=\int (T101-T102)\cdot W100\cdot dt$
Solar collector operating energy:	$Q102=\int EP101\cdot S100\cdot dt$
Collector efficiency:	$N100=(Q100/Q001)$
Solar energy to storage:	$Q200=Q100-Q101-Q500$
Solar energy to heating load:	$Q400=Q402-Q401$
Auxiliary energy to heating load:	$Q401=\int (T402-T400)\cdot W100\cdot S401\cdot dt$
Heating load:	$Q402=\int (T403-T401)\cdot W400\cdot S400\cdot dt$
Solar heating loop operating energy:	$Q403=\int EP400\cdot(S400-S401)\cdot dt$
Solar energy to absorption chiller:	$Q500=\int (T500-T100)\cdot W100\cdot S505\cdot dt$
Cooling load:	$Q502=\int (T501-T503)\cdot W500\cdot S500\cdot dt$
Absorption chiller operating energy:	$Q503=\int (EP500+EP504+EP505)\cdot S505\cdot dt$
Absorption chiller load:	$Q505=\int (T501-T502)\cdot W505\cdot S505\cdot dt$
Electric chiller load:	$Q506=\int (T502-T503)\cdot W506\cdot S506\cdot dt$
Absorption chiller coefficient of performance:	$N500=Q505/(Q503+Q102)$
Energy saved:	$Q606=Q400+Q500-Q102-Q403-Q503$
Dollars saved:	$D606=\left(Q400-Q403-(Q102\cdot Q400)/(Q400+Q500)\right)\cdot HTCOST+\left(Q500-Q503-(Q102\cdot Q500)/(Q400+Q500)\right)\cdot CLCOST$
Hours of useful solar energy:	$S001=\begin{cases}0.0 \text{ if } I001<MININ\\ 1.0 \text{ if } I001>MININ\end{cases}$ $H001=\int S001\, dt$

Figure 2-14. System Performance Calculations. (Courtesy Remtech)

```
26 AUG 79     11:30 A.M.
                                    ENERGY SAVED
YESTERDAY               1.232E+05 Btu                          $  100.00
LAST 30 DAYS            3.002E+06 Btu                          $ 1000.00
LAST 365 DAYS           9.079E+07 Btu                          $ 1000.00
*************************************************************************
                            USEABLE SOLAR ENERGY AVAILABLE
YESTERDAY                10.2 Hours
LAST 30 DAYS            261.6 Hours
LAST 365 DAYS          1257.3 Hours
*************************************************************************
                                  SYSTEM PARAMETERS
COLLECTOR INLET TEMPERATURE                              178.9 F
COLLECTOR OUTLET TEMPERATURE                             200.5 F
STORAGE TANK TEMPERATURE                                 179.0 F
OUTDOOR AIR TEMPERATURE                                   66.2 F
SOLAR INTENSITY                                           88.2 Btu/sq Ft Hour
COLLECTOR PUMP ON
BOILER OFF
SOLAR CHILLER OFF
ELECTRIC CHILLER OFF
*************************************************************************
```

Figure 2-15. SDAR Display on Lobby Terminal.
(Courtesy Remtech)

SECTION 3
SYSTEM OPERATION

The solar heating system operational controls have been interfaced with the standard Heating, Ventilating, and Air Conditioning (HVAC) controls. The operation of this combined solar heating-HVAC system is keyed to the solar collector output temperature; the ambient air temperature; temperature within the solar distribution/storage system and standardized air handling units; and the building space thermostats. Operation of the combined system is automatic and should require no action during operation except for adjusting or setting building space thermostats, or emergency conditions such as power or component failures, system leaks, and extreme low temperature. (Ref. Appendix C for detailed operation and drawings.)

3.1 FILLING AND DRAINING PROCEDURES

Make-up water is provided to the solar system by an automatic fill valve at the expansion tank. Make-up of the water in the boiler/air handler loop is accomplished indirectly through the 5000 gallon storage tank. The cooling tower and mechanical chiller loops also have water make-up valves which are components of the conventional HVAC system.

For initial fill, the solar hot water loop is equipped with manual valves at the inlet and outlet to the solar hot water pumps A & B and bleed valves in the roof curbs (see Figure 3-1). Regardless of the position of valves V4 and V6, the 5000 gallon storage tank will fill from city water pressure, and water will enter the collectors regardless of the position of valve V1.

As a safety precaution, the solar collectors were covered with black Visqueen until they were adequately filled with water so the individual collector tubes would not experience high thermal shock as cold city water entered the tubes.

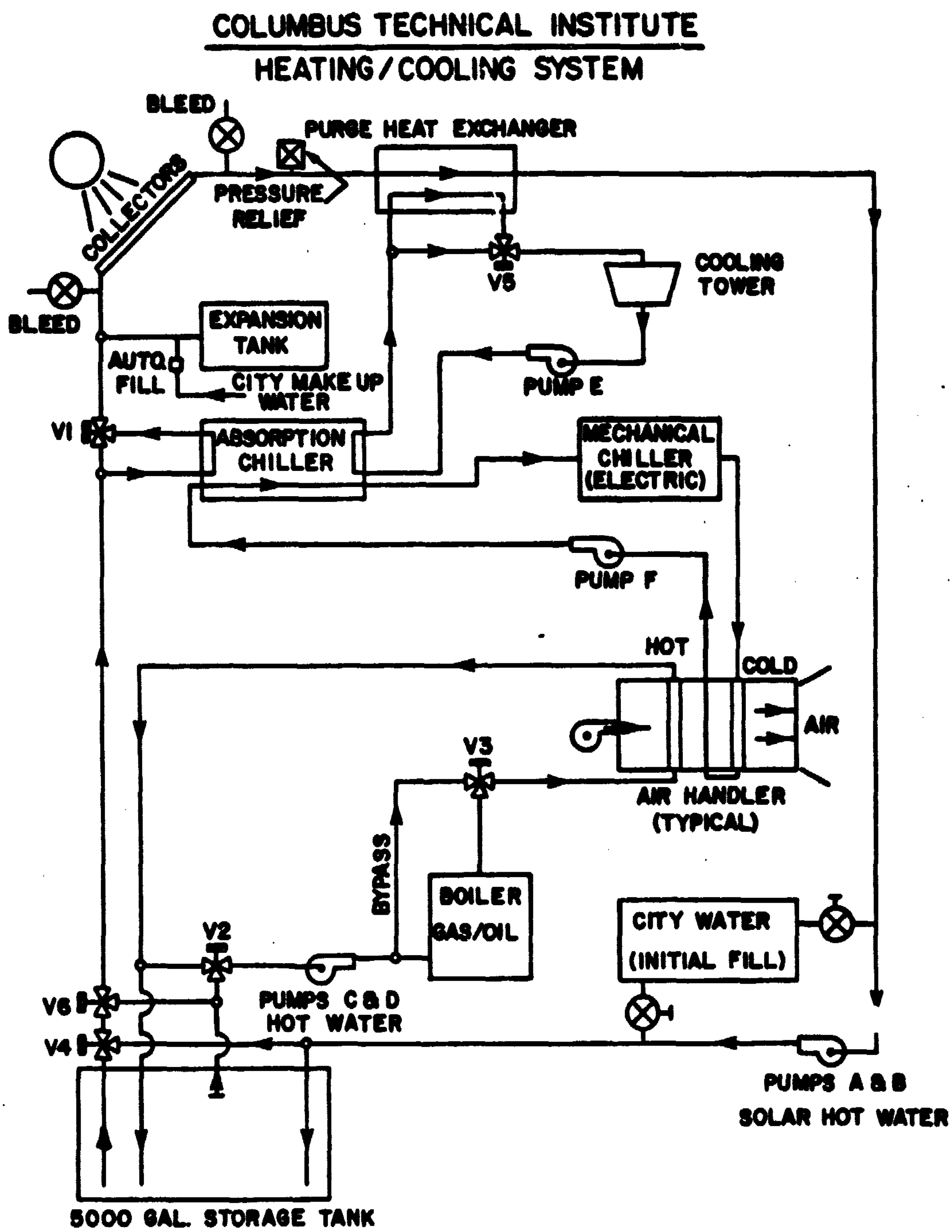


Figure 3-1. Filling and Draining Schematic.
(Courtesy Heapy & Associates)

To fill the boiler/air handler loop, valve V2 was opened to permit flow from the storage tank to the pumps C&D inlet. Pumps C&D filled the remainder of the loop. Valves V1, V3, and V5 were excercised to fill the bypass lines.

3.2 EMERGENCY DRAINING

If a collector tube is broken, the resulting leak will be detected by a system which warns the Security Office in an adjoining building. Each of the eight rows of collectors on the roof can be isolated from the system by closing two manual valves in the roof curb because the eight rows are connected in parallel. The defective row must be covered with black Visqueen during hours of bright sunlight to prevent percolation of the collectors until the leak can be repaired.

If catastrophic failure of both solar heat pumps A & B occurs, or if the system develops a leak between the solar collectors on the roof and the pump/storage tank complex on the first floor and underground, then the entire solar system must be shut down immediately. All Solar collectors must be covered with black Visqueen until repairs are complete.

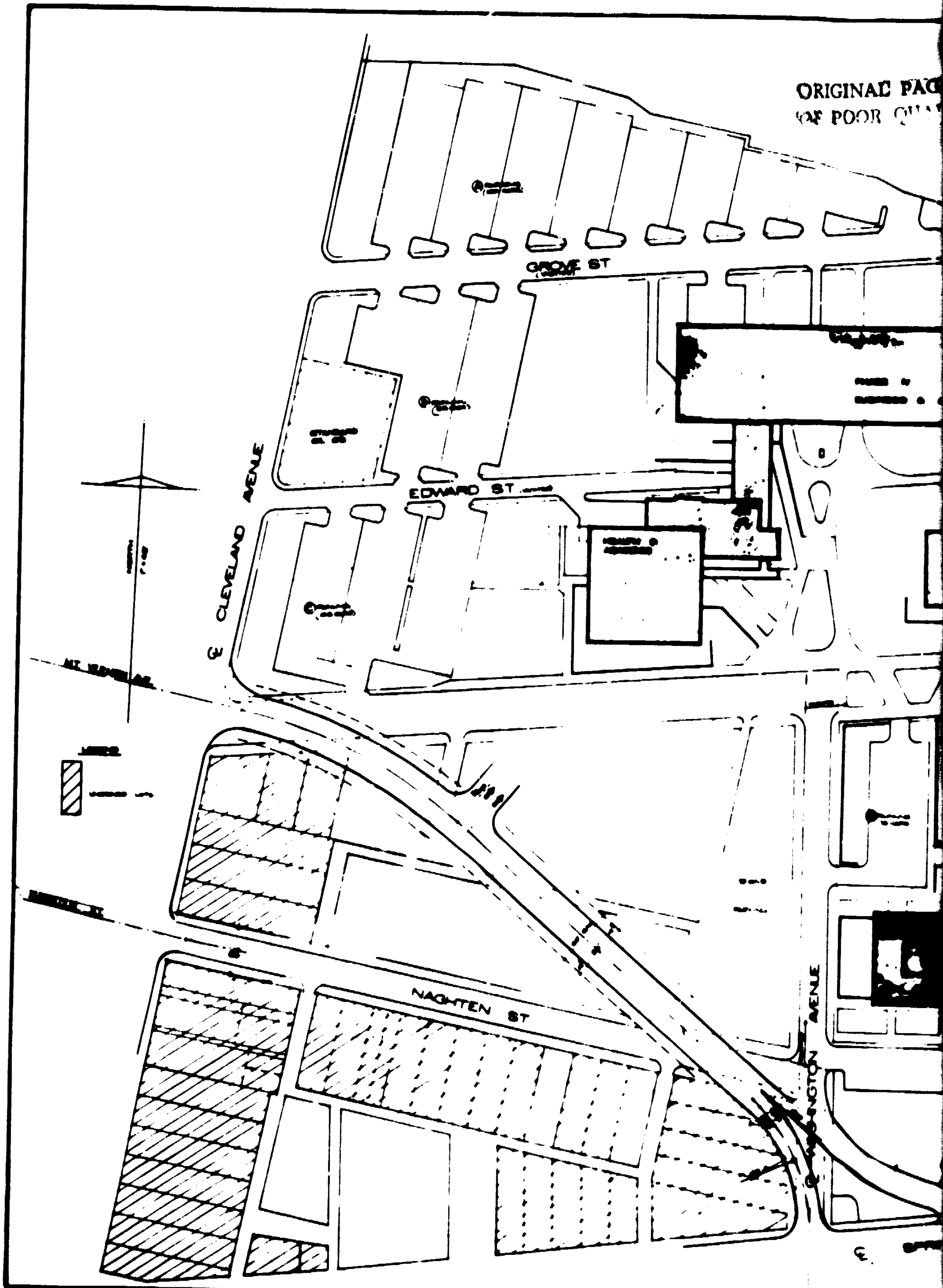
The worst possible combination of events is a catastrophic leak in the piping to or from the collectors <u>and</u> the collector temperature drops below freezing. This could only occur during the night in extreme cold. If the leak could be "contained", city water would be passed through the collectors to prevent freeze-up until the sun emerged. If the leak could not be "contained", each of the 3072 tubes would have to be drained individually before freeze-up, since there is no high-pressure air or other system to force water out of the collectors in an emergency. If hot water pumps C & D fail, or if a leak occurs in the boiler/air handler loop, no heat can be provided to the building. The solar loop can continue to provide hot water to the storage tank, but this water is not accessible to the air handlers.

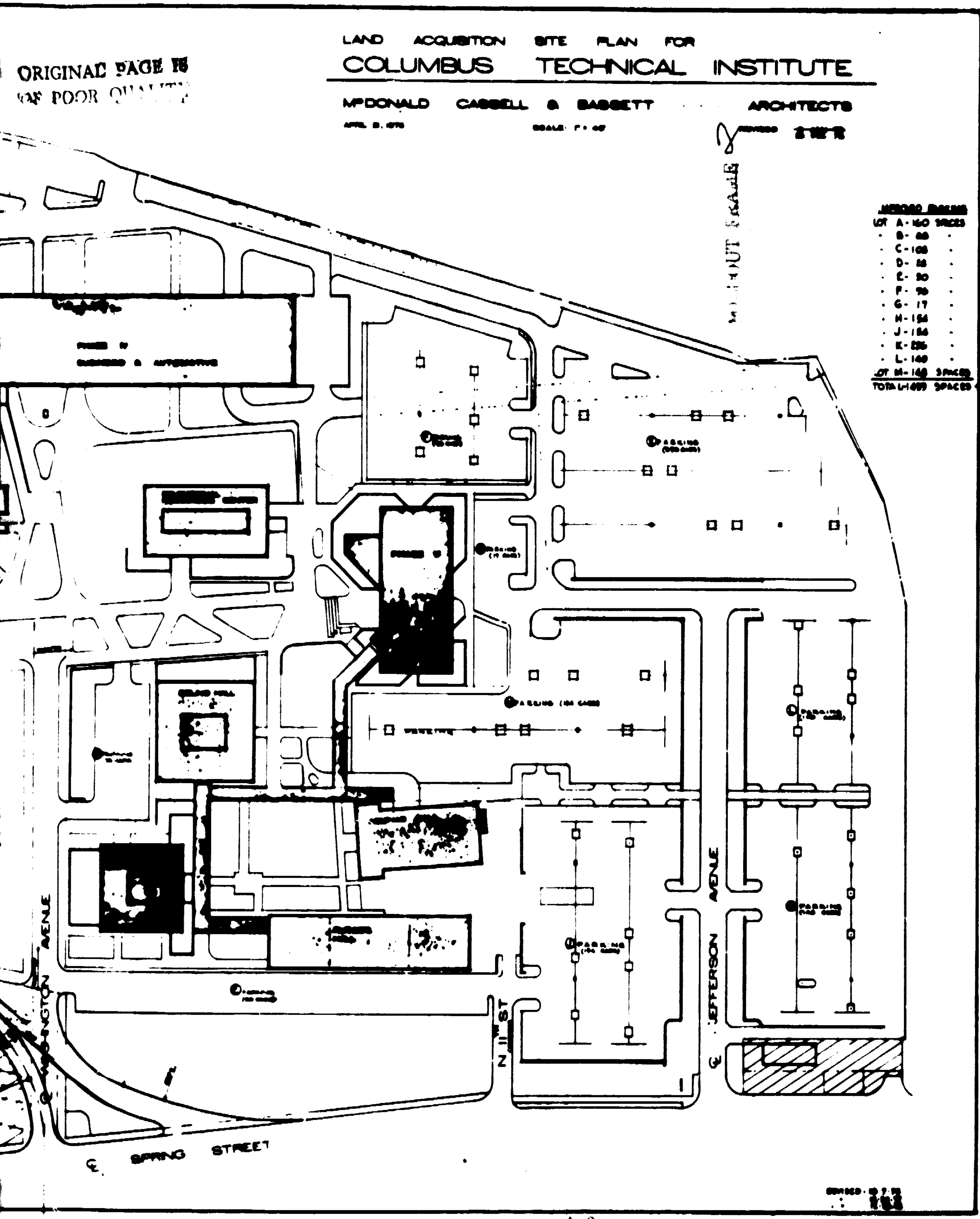
To assist maintenance personnel on restart of the system, an Acceptance Test Plan is included as Appendix E.

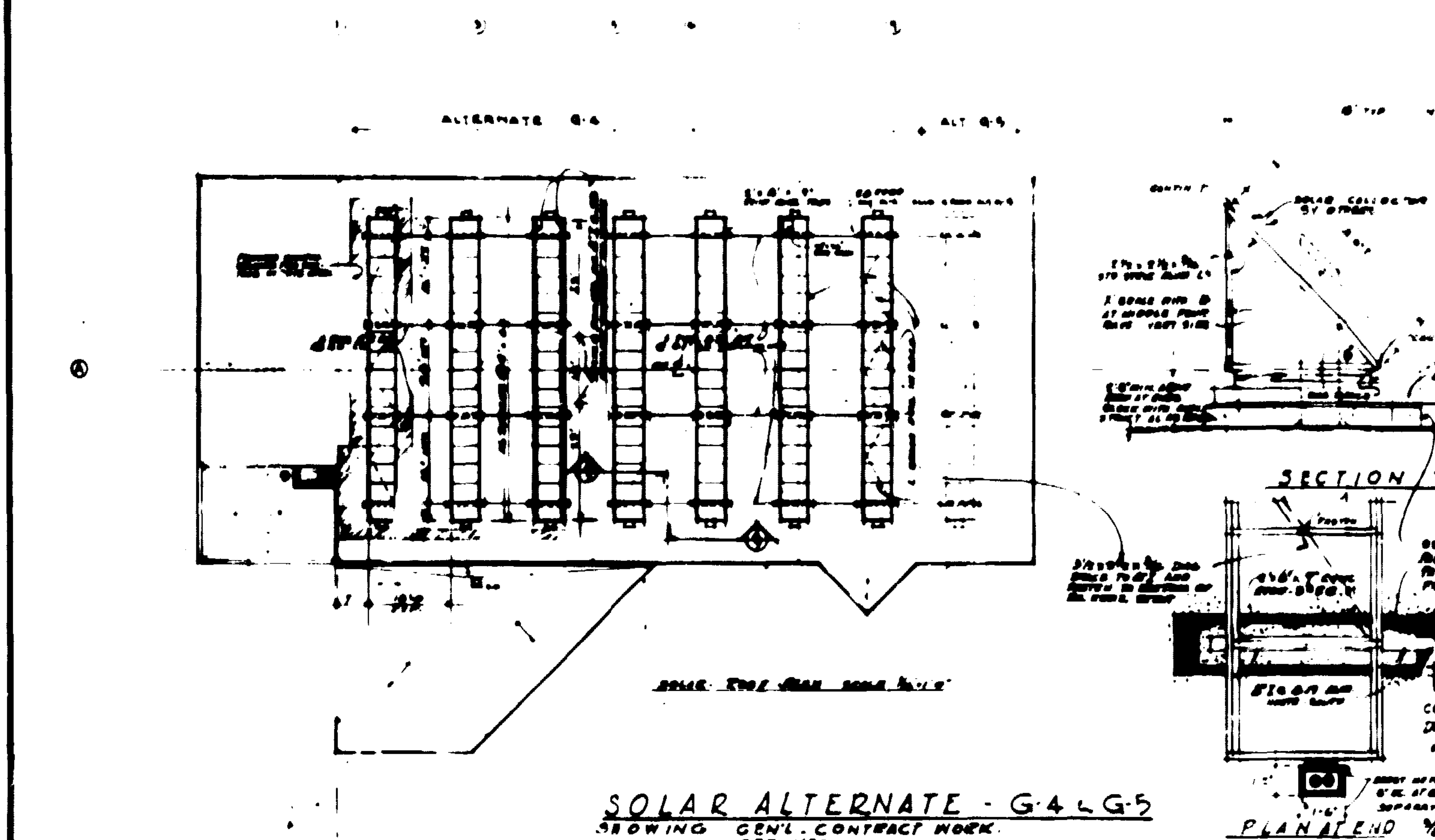
APPENDIX A
AS-BUILT DRAWINGS

FOLDOUT FRAME

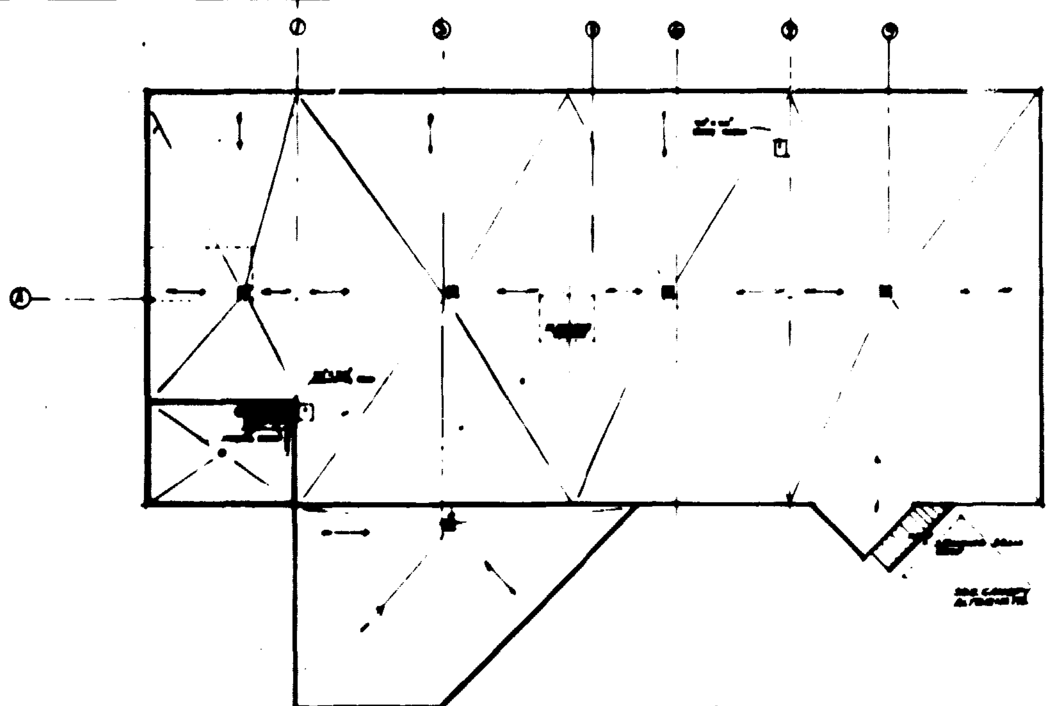
ORIGINAL PAG
OF POOR QU




LAND ACQUISITION SITE PLAN FOR
COLUMBUS TECHNICAL INSTITUTE
McDONALD CASSELL & BASSETT ARCHITECTS
LOT A-160 SPACES
G- 17
JEFFERSON AVENUE
WASHINGTON AVENUE
SPRING STREET
N 11 ST



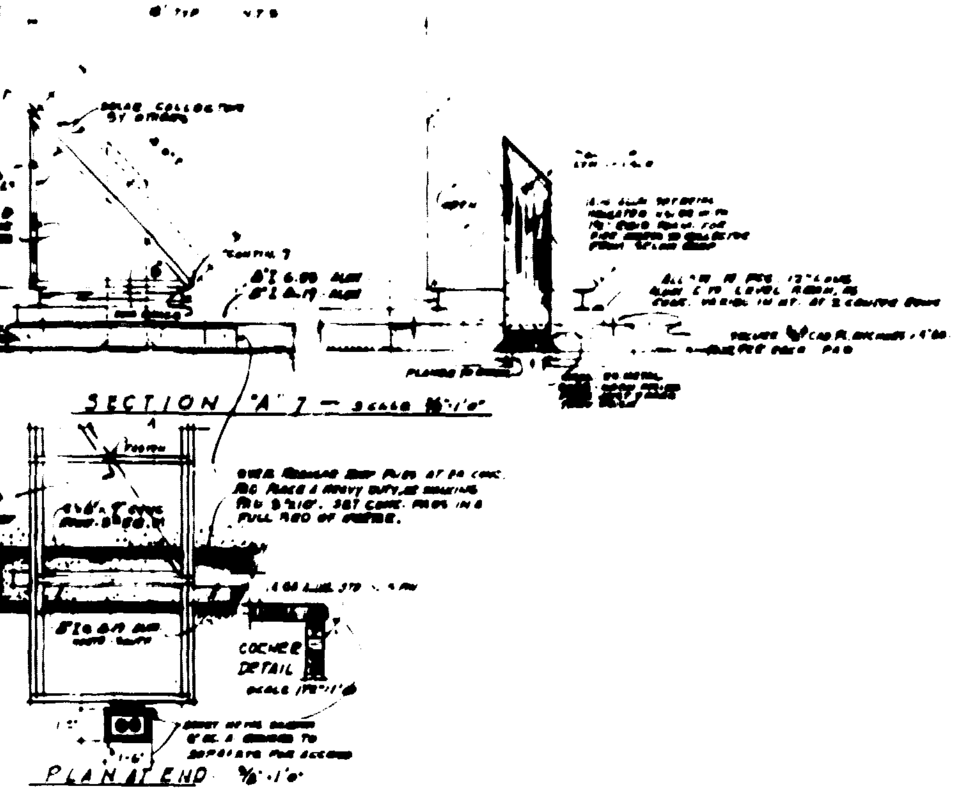
SOLAR ALTERNATE - G-4 & G-5
SHOWING GEN'L. CONTRACT WORK



ROOF PLAN

COLUMBUS TECHNICAL INSTITUTE - PHASE V BUILDING

MT. VERNON AVE COLUMBUS, OHIO



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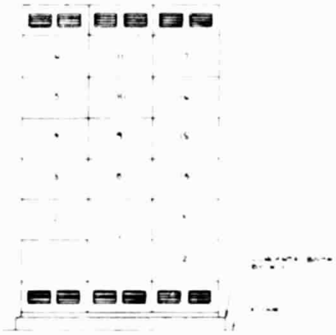
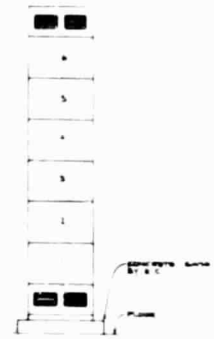
ROOF PLAN	COMM NO. 7600		ARCHITECTS	



MC2
ELEVATION



MC1
ELEVATION △

MOTOR CONTROL CENTER "MC2" △

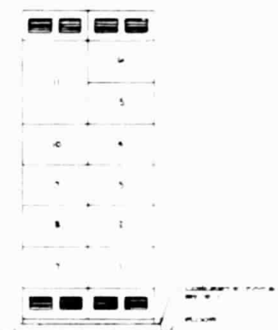
1	AH1	A.H. UNIT 1	7½	1	●		50	3	20	[illegible]
2	AH2	[illegible]	5	1	●		[illegible]	3	20	[illegible]
3	AH3	[illegible]	7½	1	●		[illegible]	3	20	[illegible]
4	AH7	[illegible]	7½	1	●		[illegible]	3	20	[illegible]
5	EF5	[illegible]	[illegible]	1	●		[illegible]	[illegible]	20	[illegible]
6	[illegible]	[illegible] COMPRESSOR	[illegible]	—		●	[illegible]	3	20	[illegible]
7	[illegible]	COOLING TOWER	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
8	[illegible]	COOLING TOWER [illegible] PUMPS	[illegible]	—		●	[illegible]	3	20	[illegible]
9	[illegible]	PUMP [illegible]	[illegible]	1	●		[illegible]	3	[illegible]	[illegible] △
10	[illegible]	[illegible] COMPRESSOR	[illegible]			●	[illegible]	3	[illegible]	[illegible] △
11	[illegible]	PUMP [illegible]	7½	1	●		[illegible]	3	20	[illegible] △
12		SPACE								△
13	[illegible]	ABSORPTION [illegible] PUMP	[illegible]	1	[illegible]		[illegible]	3	[illegible]	[illegible]
14	[illegible]	ABSORPTION CHILLER [illegible]	[illegible]	—		●	[illegible]	2	20	[illegible] △
15	[illegible]	[illegible] (ABSORPT CHILLER)	[illegible]	1	●		[illegible]	3	20	[illegible] △
16		SPACE								△
17	[illegible]	[illegible]	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]

MOTOR CONTROL CENTER "MC1" △

1	[illegible]	DOMESTIC [illegible] PUMP	½	1	●		[illegible]	3	[illegible]	[illegible]
2	[illegible]	BOILER	1½			●	[illegible]	3	[illegible]	[illegible]
3	[illegible]	PUMP 1	[illegible]	[illegible]	●		[illegible]	3	[illegible]	[illegible]
4	[illegible]	PUMP 2	[illegible]	[illegible]	●		[illegible]	3	[illegible]	[illegible]
5	[illegible]	[illegible] FAN [illegible]	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
6		SPACE								

MOTOR CONTROL CENTER "MC3"

1	AH5	A.H. UNIT 5	[illegible]	1	●		[illegible]	3	20	[illegible]
2	AH6	A.H. UNIT 6	[illegible]	1	●		[illegible]	3	20	[illegible]
3	AH4	A.H. UNIT 4	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
4	AH8	A.H. UNIT 8	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
5	AH9	A.H. UNIT 9	2	1	●		[illegible]	3	[illegible]	[illegible]
6	EF1	EXH FAN 1	[illegible]	1	●		[illegible]	3	20	[illegible]
7	EF2	EXH FAN 2	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
8	EF3	EXH FAN 3	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
9	EF4	EXH FAN 4	[illegible]	1	●		[illegible]	3	[illegible]	[illegible]
10	EF7	EXH FAN 7	[illegible]	1	●		[illegible]	3	20	[illegible]
11		SPACE FOR FUTURE								



MC3
ELEVATION

FOLDOUT FRAME

CENTER "MCI"

MOTORS, STARTERS, DISCONNECTS & CONTROLS

Motor	HP	Location
A.H. UNIT #1	1½	[illegible]
A.H. UNIT #2	[illegible]	⇩
A.H. UNIT #3	1½	⇩
A.H. UNIT #4	[illegible]	[illegible]
A.H. UNIT #5	[illegible]	⇩
A.H. UNIT #6	5	⇩
A.H. UNIT #7	7½	[illegible]
A.H. UNIT #8	[illegible]	[illegible]
A.H. UNIT #9	2	[illegible]
EXH. FAN #1	1½	[illegible]
EXH. FAN #2	¾	⇩
EXH. FAN #3	½	⇩
EXH. FAN #4	½	⇩
EXH. FAN #5	½	[illegible]
EXH. FAN #6	1/6	[illegible]
EXH. FAN #7	½	[illegible]
EXH. FAN #8	½	[illegible]
EXH. FAN #9	1/6	[illegible]
EXH. FAN #10	¾	[illegible]
[illegible]	¼	[illegible]
[illegible]	½	[illegible]
[illegible]	[illegible]	[illegible]
PUMP #1	15	[illegible]
PUMP #2	[illegible]	[illegible]
PUMP #3	15	[illegible]
PUMP #4	7½	[illegible]
COOLING TOWER	10	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	1½	[illegible]
[illegible]	5½	[illegible]
[illegible]	5½	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
CHEMICAL FEEDER	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
SUMP PUMP	[illegible]	ELEVATOR PIT
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
WATER HEATER	[illegible]	⇩
[illegible]	[illegible]	ENTRY [illegible]
[illegible]	[illegible]	ENTRY [illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
ELEVATOR	40	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

NOTES:
1. STARTED ... 2 SPEED ... WINDING ... TIME DELAY
2. ... PROTECTION ... MOTOR
3. COMBINATION MAGNETIC STARTER
4. CONTROL FROM REMOTE SWITCHES ...
5. MANUAL CONTROL FROM ROOM SWITCH

REVISIONS
... REVISIONS ACCORDING TO SOLAR SYSTEM CHANGES

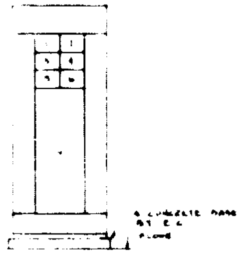
HEAPY & ASSOCIATES
CONSULTING ENGINEERS
DAYTON - COLUMBUS OHIO

MOTOR & STARTER SCHEDULES

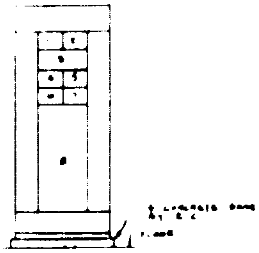
COMM. NO. 7605

McDONALD, CASSELL & BASSETT
ARCHITECTS
457 N. HIGH ST. COLUMBUS, OHIO

E-6
of 53



"SDP2" ELEVATION



"SDP1" ELEVATION

SUB-DIST. PANEL "SDP2"

FEEDER: [illegible] BUSSING: 400 AMP [illegible] VOLT – 3 Ø – 4 W. [illegible]

NO.	SERVICE	OVERCURRENT PROTECTION					FEEDERS			
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	PANEL "3C"	100	3	100	STD	15.2	4	2	8	1½"
2	PANEL "1C"	100	3	100	STD	[illegible]	4	2	8	1½"
3	PANEL "2C"	100	3	100	STD	[illegible]	4	2	8	1½"
4	PANEL "3D"	100	3	100	STD	[illegible]	4	2	8	1½"
5	PANEL "3E"	100	3	100	STD	20.0	4	2	8	1½"
6	SPARE SWITCH	100	3	—	—	—	—	—	—	—
7	SPACE FOR FUTURE SWITCHES	—	—	—	—	—	—	—	—	—

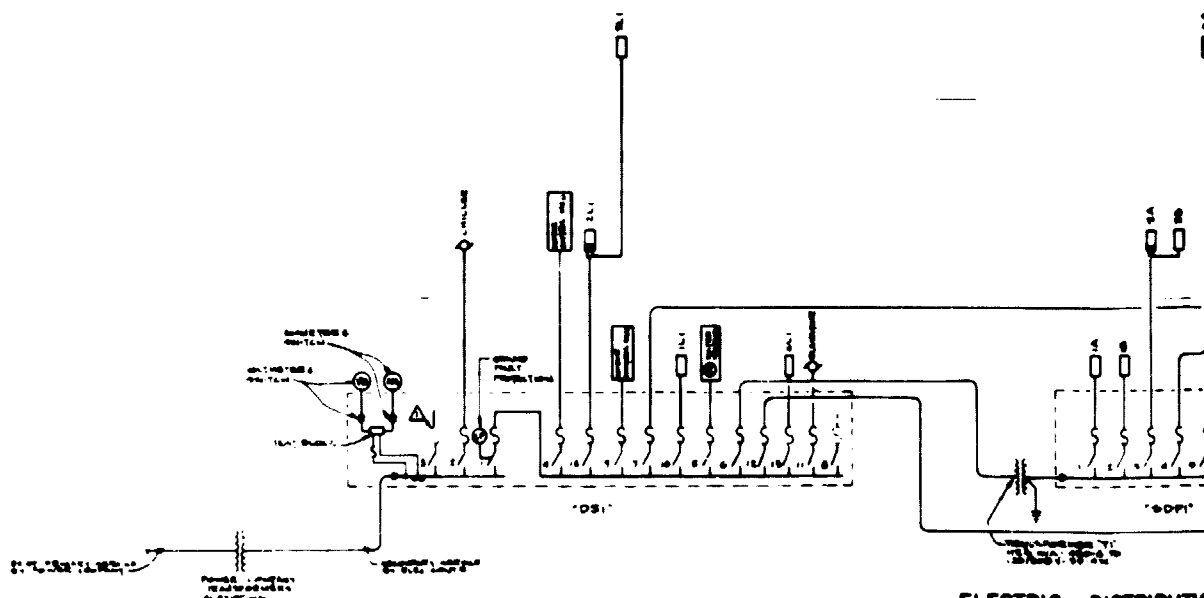
NOTES:
1. CONNECTED LOAD IS [illegible] KW WITH ESTIMATED DEMAND LOAD AT [illegible] KW

SUB-DIST. PANEL "SDP1"

FEEDER: [illegible] BUSSING: [illegible] [illegible] VOLT – 3 Ø – 4 W. [illegible]

NO.	SERVICE	OVERCURRENT PROTECTION					FEEDERS			
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	PANEL "1A"	[illegible]	3	[illegible]	STD	[illegible]	4	2	8	1½"
2	PANEL "1B"	100	3	100	STD	[illegible]	4	2	8	1½"
3	PANELS "2A" & "2B"	[illegible]	3	[illegible]	STD	[illegible]	4	[illegible]	6	[illegible]
4	PANEL "3A"	100	3	100	STD	[illegible]	4	2	8	1½"
5	PANEL "3B"	100	3	100	STD	[illegible]	4	2	8	1½"
6	SPARE SWITCH	[illegible]	3	—	—	—	—	—	—	—
7	SPARE SWITCH	100	3	—	—	—	—	—	—	—
8	SPACE FOR FUTURE SWITCHES	—	—	—	—	—	—	—	—	—

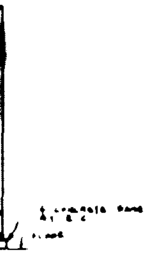
NOTES:
1. CONNECTED LOAD IS [illegible] KW WITH ESTIMATED DEMAND LOAD AT [illegible] KW

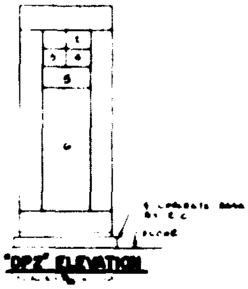


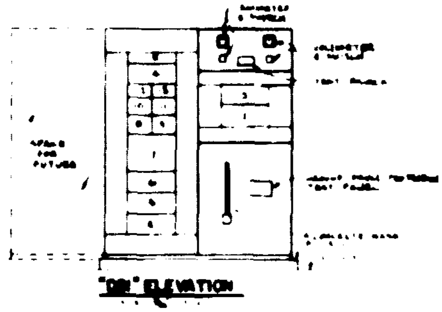
ELECTRIC DISTRIBUTI

COLUMBUS TECHNICAL INSTITUTE - PHASE V BUILDING

MT VERNON AVE COLUMBUS, OHIO







[illegible] L "SDP1"

STD	55.10	4	2	8	1½"
STD	15.00	4	2	8	1½"
STD	60.00	4	½	6	1½"
STD	11.00	4	2	8	1½"
STD	10.0	4	2	8	1½"
—	—	—	—	—	—
—	—	—	—	—	—
—	—	—	—	—	—

DIST. PANEL "DP2"

FEEDER: [illegible] TYPE: [illegible]
BUSSING: [illegible] AMP 277/480 VOLT — 3 Ø — 4 W. [illegible]

NO.	SERVICE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	MOTOR CONTROL CENTER "MC5"	100	3	100	LPS	31.64	3	2	8	1½"
2	SPARE SWITCH	100	3	—	—	—	—	—	—	—
3	PANEL "IL2"	100	3	100	LPS	37.15	4	2	8	1½"
4	SPARE SWITCH	100	3	—	—	—		—	—	—
5	TRANSFORMER "T2" ([illegible])	200	3	125	LPS	101.75	3	2/0	6	1½"
6	SPACE FOR FUTURE SWITCHES	—	—	—	—	—	—	—	—	—

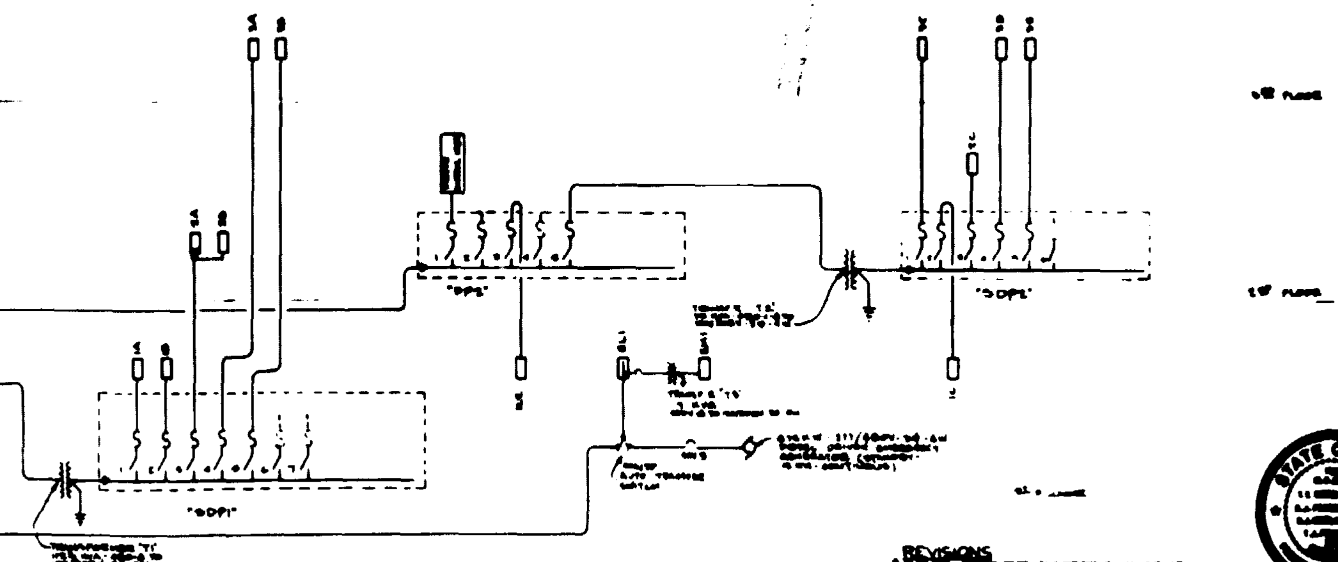
NOTES:
1. CONNECTED LOAD IS 168.95 KW WITH ESTIMATED DEMAND LOAD AT 117 KW

DIST. SWITCHGEAR "DS1" △

FEEDER: [illegible] TYPE: [illegible]
BUSSING: [illegible] AMP [illegible] 480 VOLT [illegible]

NO.	SERVICE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	MAIN SWITCH [illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		—
2	[illegible] SWITCH [illegible]	[illegible]	3	[illegible]	LPS	[illegible]	3	[illegible]	6	2"
3	SPARE	200	3	—	—	—	—	—	—	—
4	MOTOR CONTROL CENTER MC2	100	3	100	LPS	[illegible]	3	[illegible]	6	2"
5	WATER HEATER [illegible]	100	3	15	LPS	[illegible]	3	[illegible]	8	1½"
6	TRANSFORMER [illegible]	200	3	200	LPS	[illegible]	3	[illegible]	6	2"
7	DIST. PANEL "DP2"	600	1	600	LPS	[illegible]	4	[illegible]	1	3"
8	SPARE SWITCH	60	3			—	—	—	—	—
9	MOTOR CONTROL CENTER MC	100	3	60	LPS	[illegible]	3	2	8	[illegible]
10	PANEL "[illegible]"	60	3	100	[illegible]	[illegible]	4	2	8	[illegible]
11	ELEVATOR [illegible]	100	3	100	LPS	[illegible]	3	2	8	[illegible]
12	[illegible] FEED TO PANEL [illegible]	60	3	60	[illegible]	[illegible]	4	8	8	1"
13	PANEL "DL1"	60	3	60	[illegible]	[illegible]	4	6	10	[illegible]
14	PANELS "[illegible]" & "[illegible]"	200	3	200	LPS	[illegible]	4	[illegible]	6	1½"
15	SPACE FOR FUTURE SWITCHES									

NOTES:
CONNECTED LOAD IS [illegible] KW WITH ESTIMATED DEMAND LOAD AT [illegible] KW



REVISIONS
△ [illegible]

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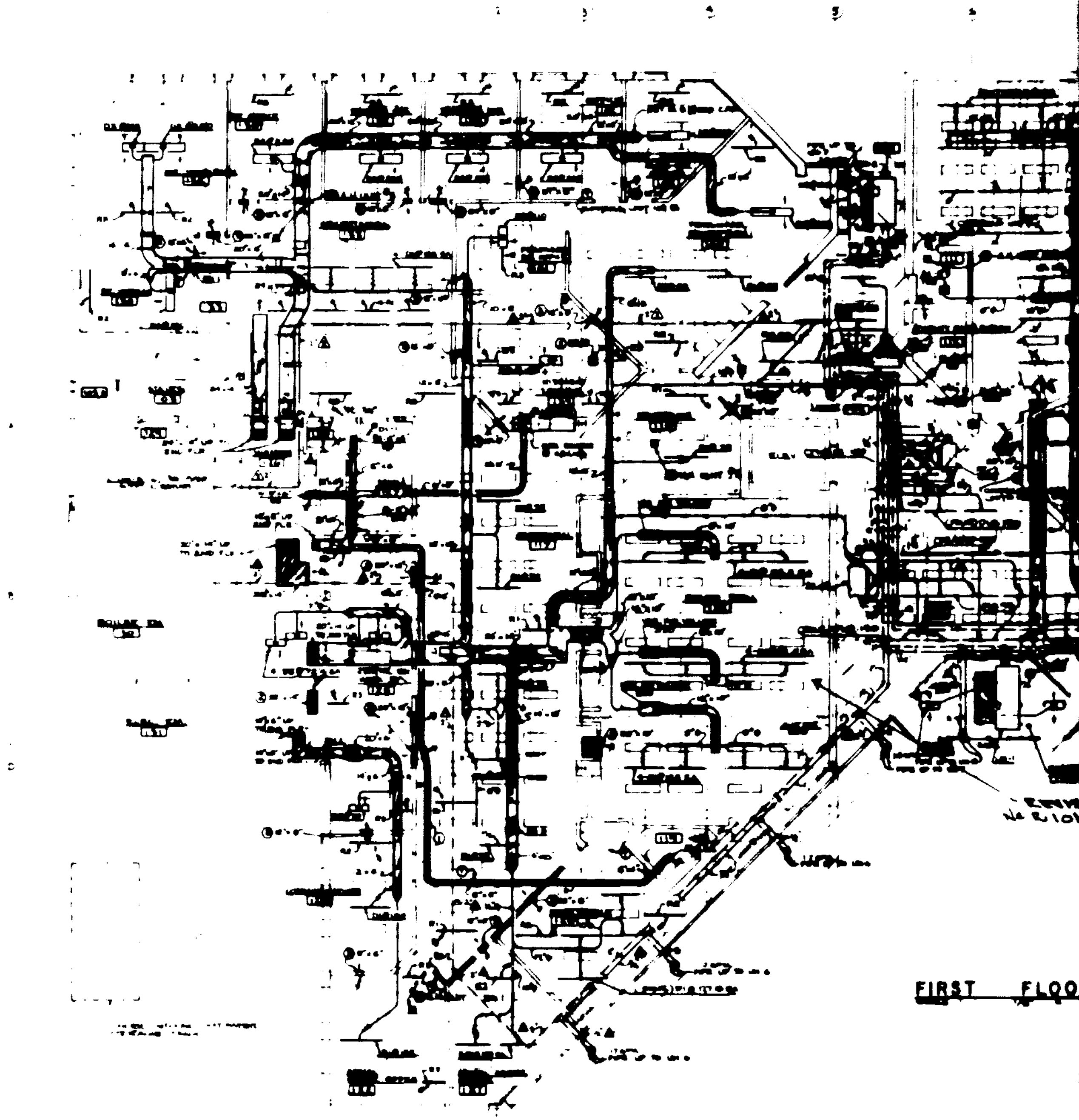
ELECTRICAL DISTRIBUTION	COMM. NO. 7606	[illegible]	McDONALD, CASSELL & BASSETT ARCHITECTS	E-7



LEGEND

COLUMBUS TECHNICAL INSTITUTE - PHASE V BUILDING

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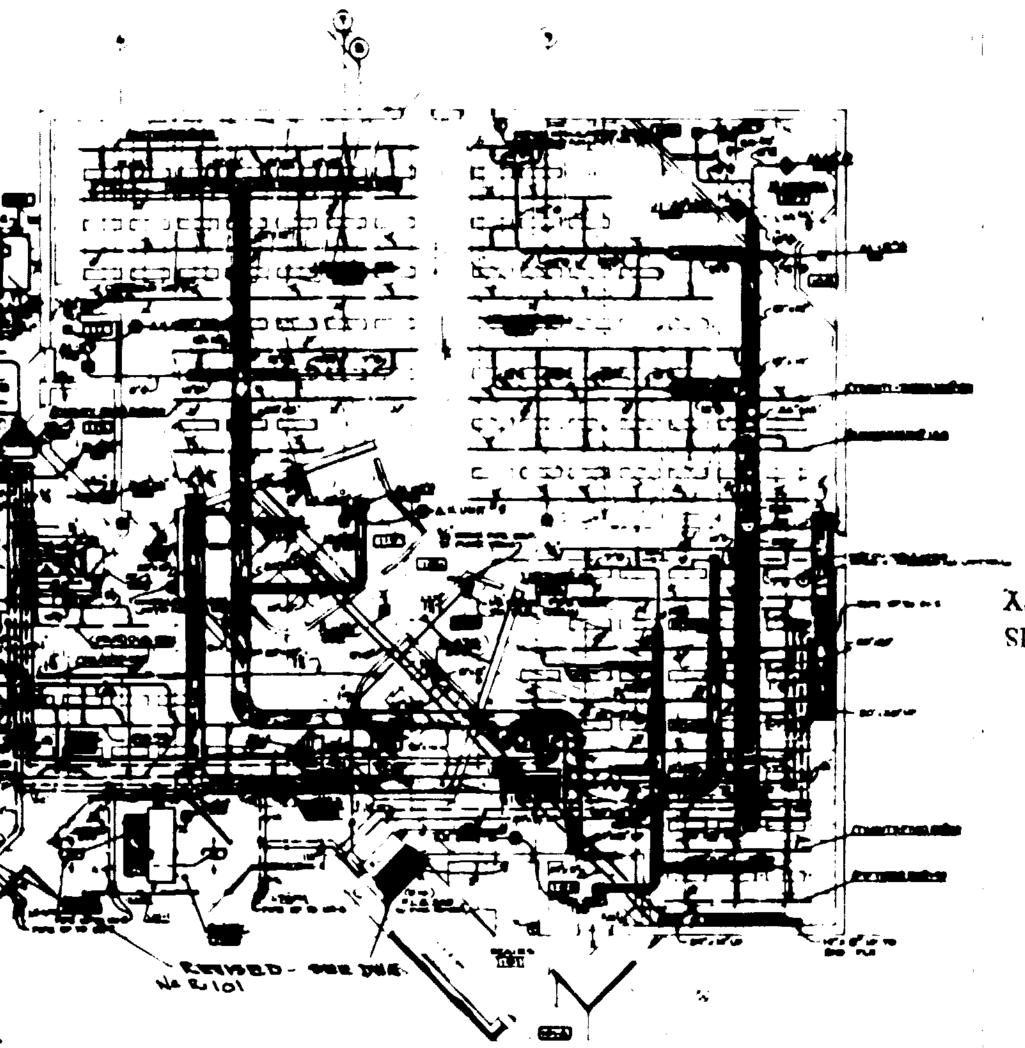
FOLDOUT FRAME

NOTES



FIRST FLOOR PLAN

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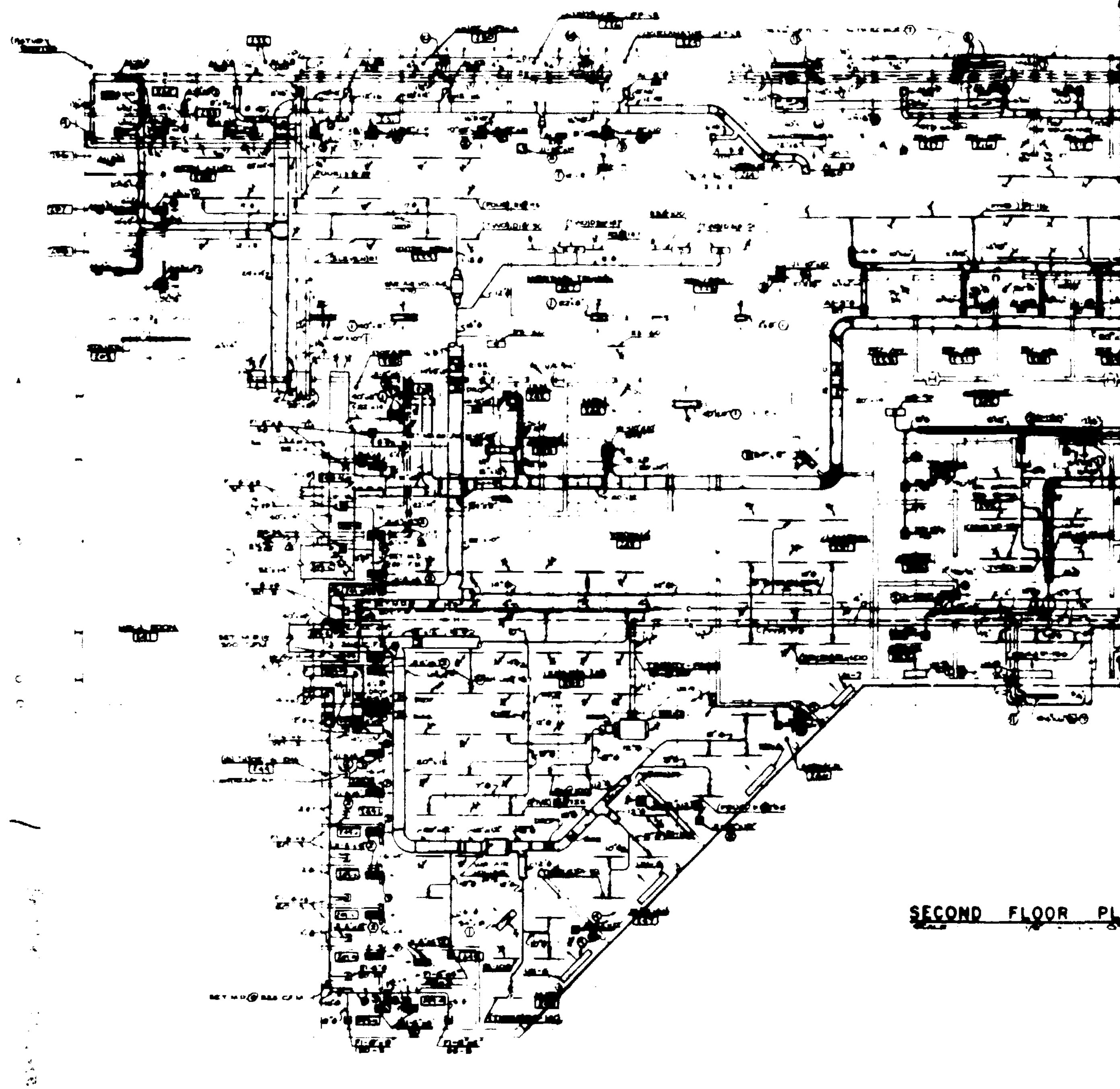
REVISIONS

Ref. Bulletin No 13

FIRST FLOOR PLAN	COMM NO 7605		ARCHITECTS	M-1



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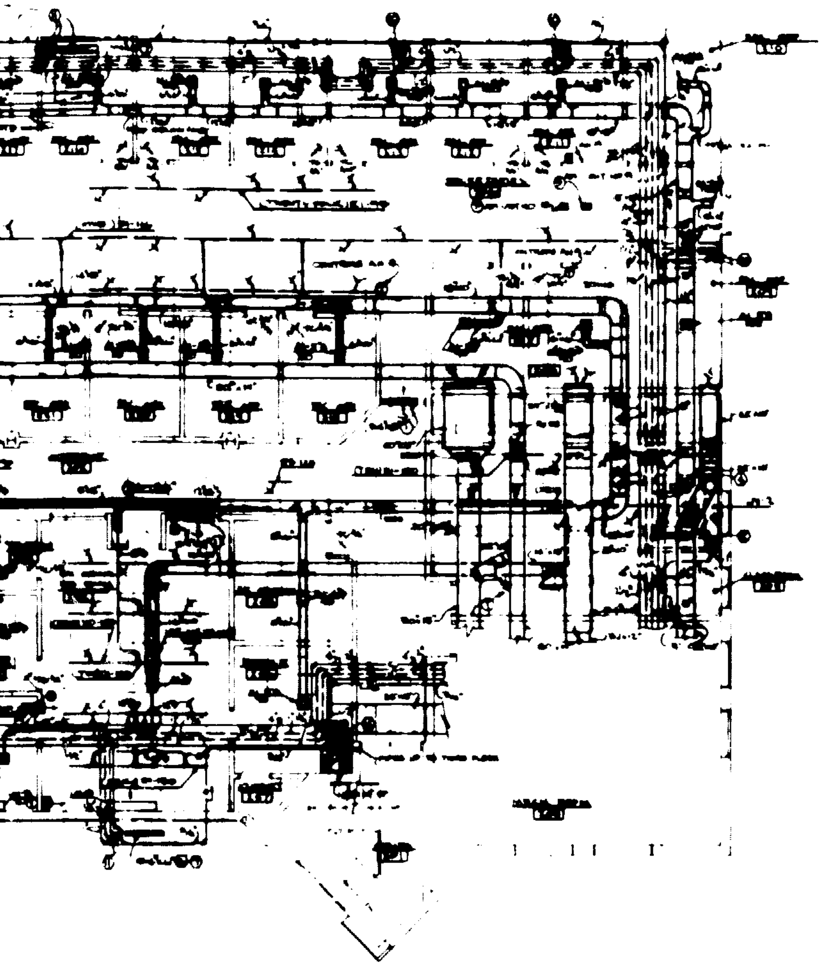
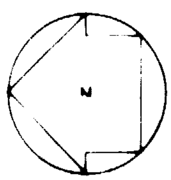


SECOND FLOOR PLAN

NOTES

1. SHEETMETAL SLEEVE THRU WALL ABOVE CEILING SIZE AS NOTED
2. GRILLE OPEN TO RETURN AIR SPACE ABOVE CEILING
3. DUCT OPEN TO SPACE ABOVE CEILING
4. [illegible]
5. [illegible]
6. [illegible]
7. [illegible]
8. DUCT TIGHT TO [illegible]
9. 1½" HOT & CHILLED WATER SUPPLY AND RETURN UP TO [illegible]
10. 1½" HOT & CHILLED WATER SUPPLY AND RETURN UP TO [illegible]
11. 1½" HOT & CHILLED WATER SUPPLY AND RETURN UP TO [illegible]
12. 1" CHILLED PIPE SUPPLY & RETURN UP TO [illegible] 1½" HOT WATER PIPE SUPPLY & RETURN UP TO [illegible]
13. [illegible] SOLAR SUPPLY & RETURN [illegible] EXPANSION LINE RISING UP TO THIRD FLR.
14. 3" CHILLED SUPPLY & RETURN PIPE UP TO THIRD FLR.
15. 2" HOTWATER SUPPLY & RETURN PIPE UP TO THIRD FLR.

REVISIONS
[illegible] SOLAR SYSTEM CHANGES [illegible]
[illegible] PARTIAL DRAWING UPDATE PER [illegible] SOLAR SYSTEM PIPE SIZE



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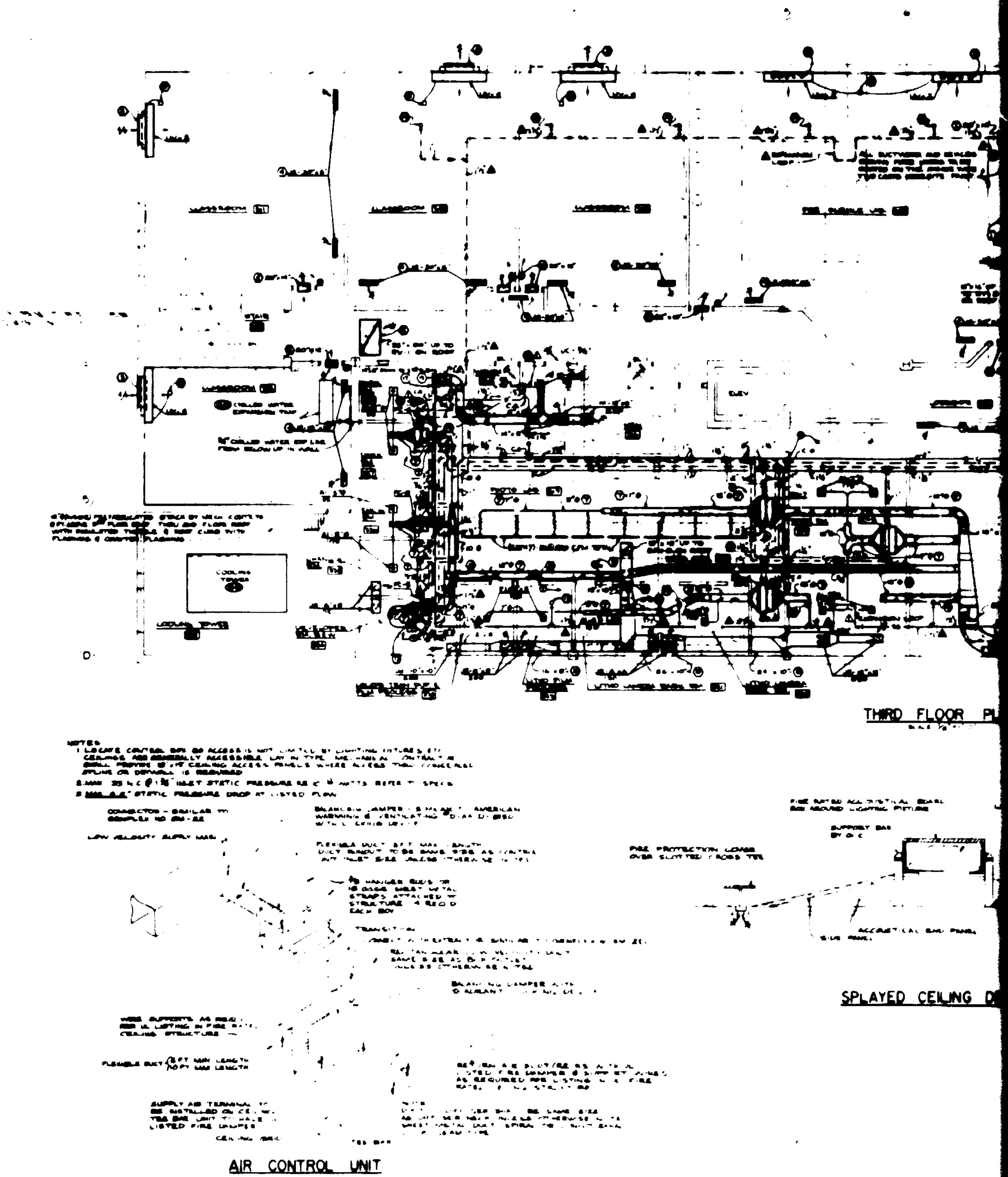
SECOND FLOOR PLAN	COMM NO 7606	[illegible]	McDONALD, CASSELL & BASSETT ARCHITECTS [illegible] N. HIGH ST. COLUMBUS, OHIO	M-2



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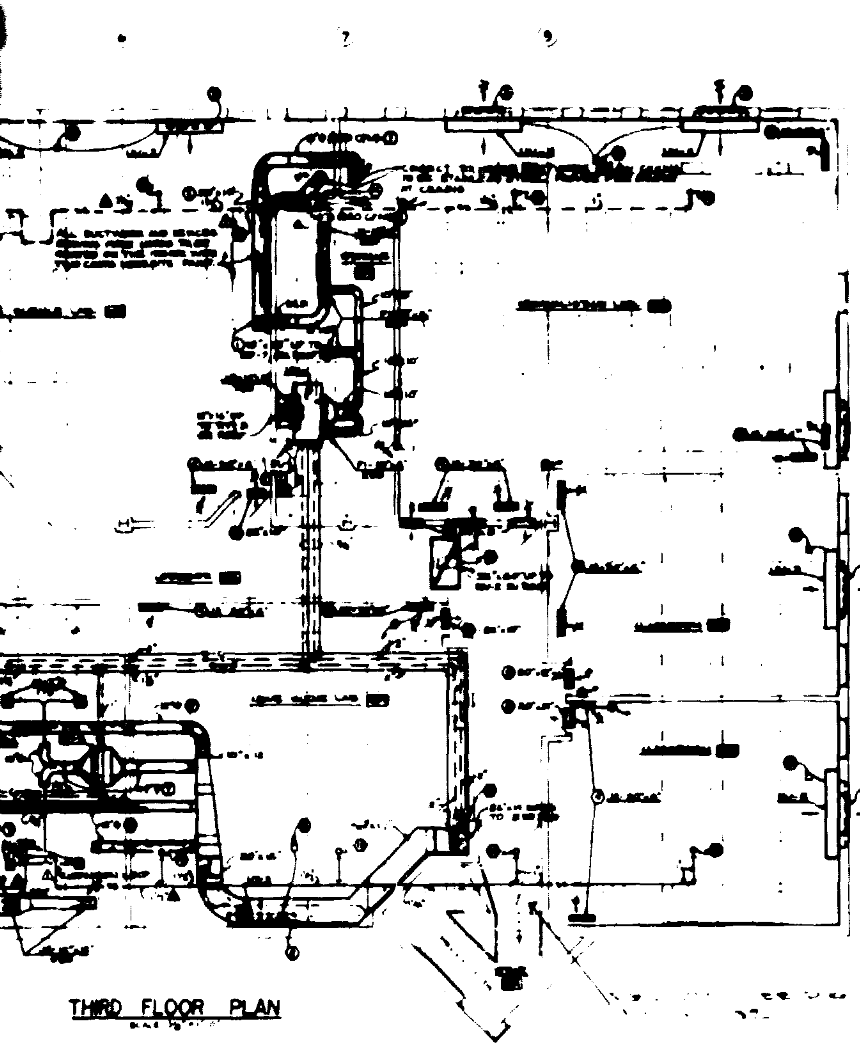
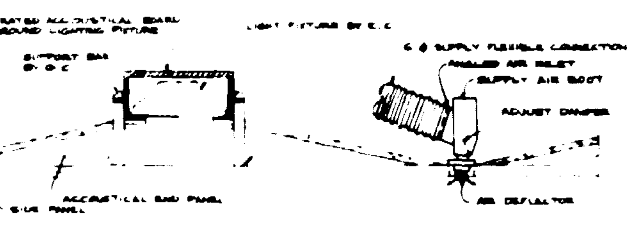
FOLDOUT FRAME

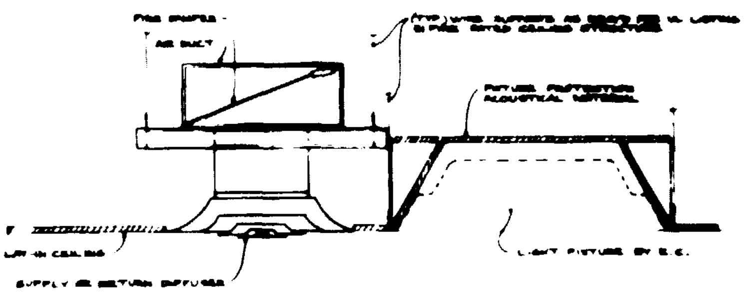
NOTES



THIRD FLOOR PLAN



SPLAYED CEILING DETAIL



FLAT CEILING DETAIL

REVISIONS

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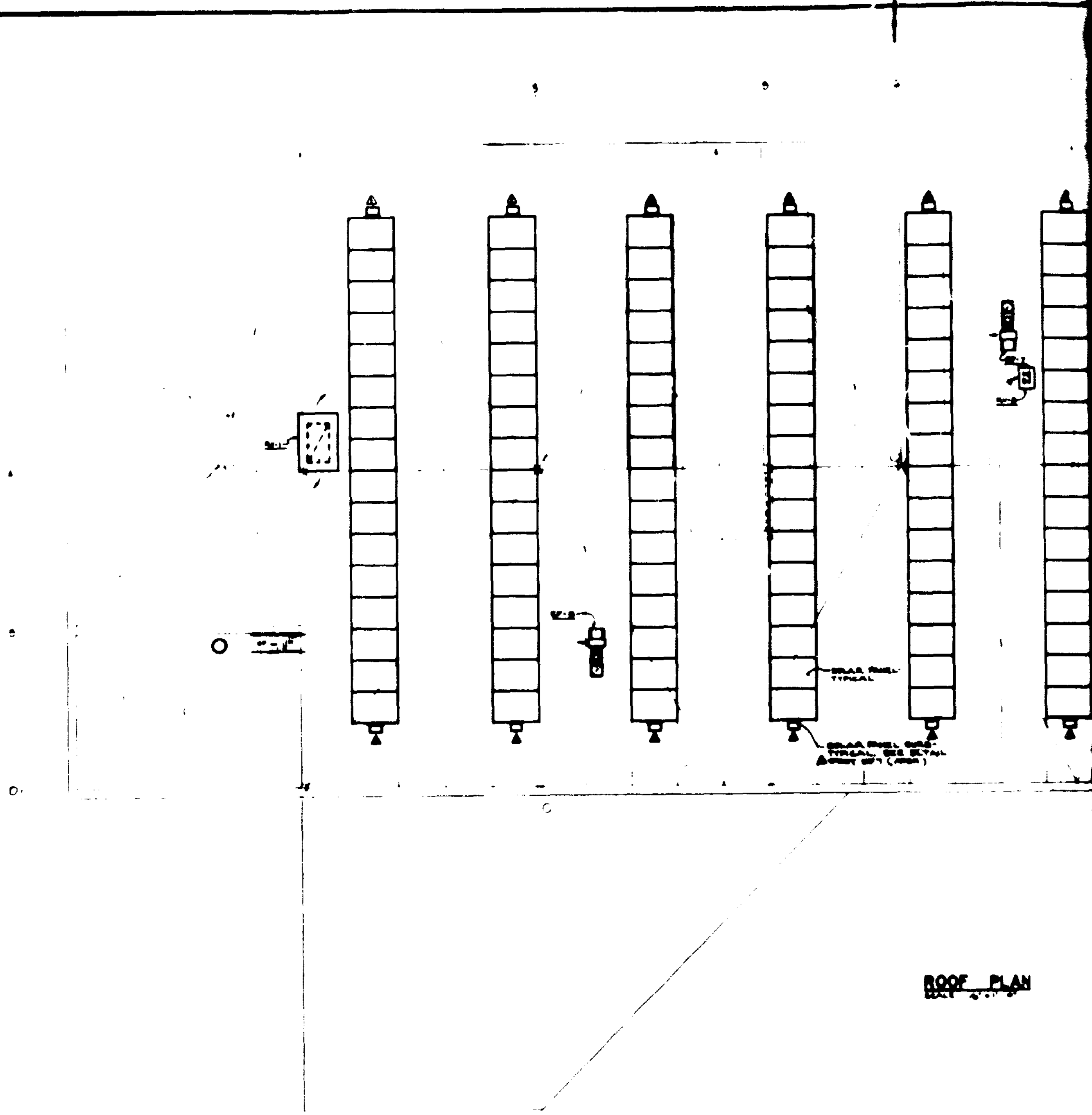
FOLDOUT FRAME



ROOF PLAN

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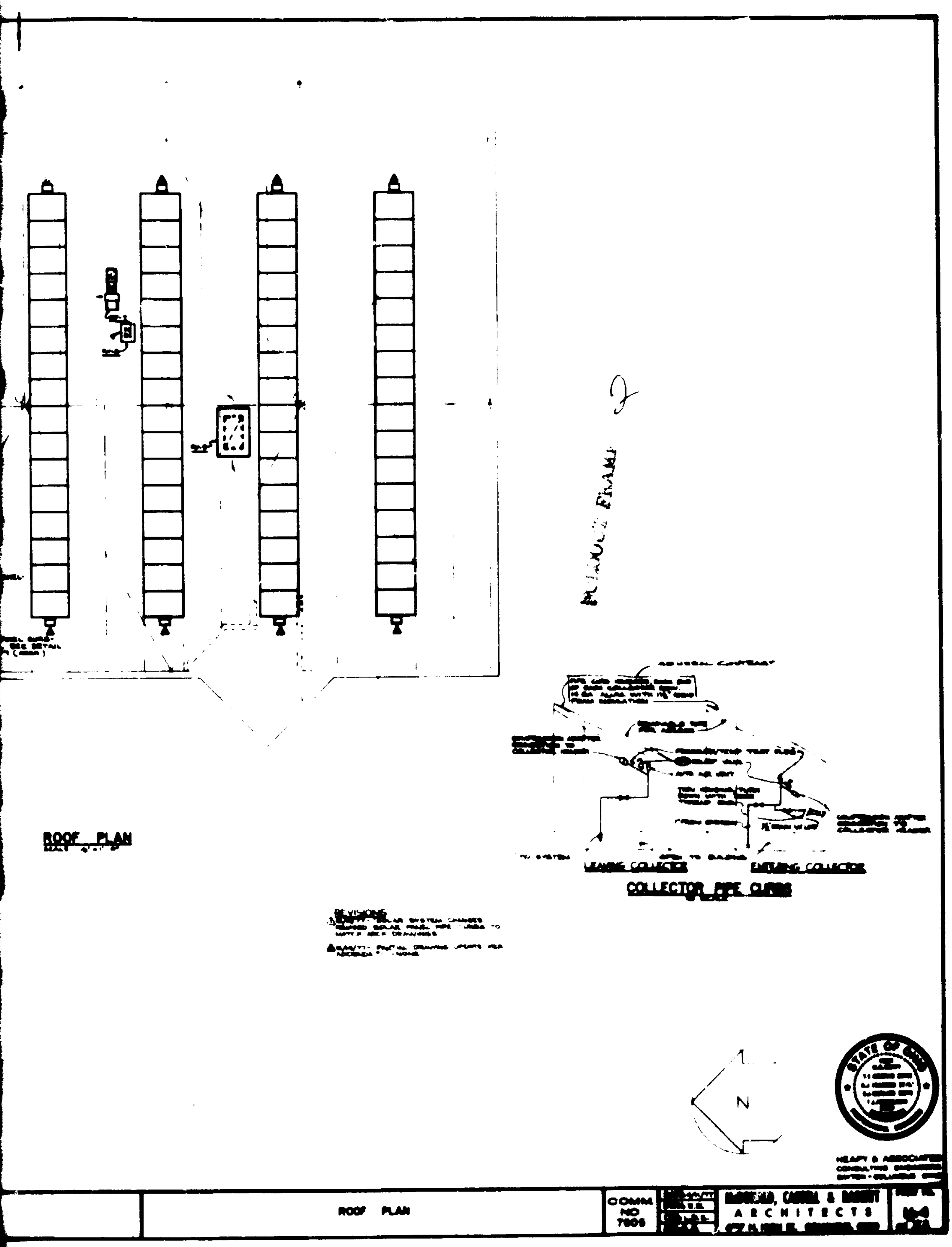
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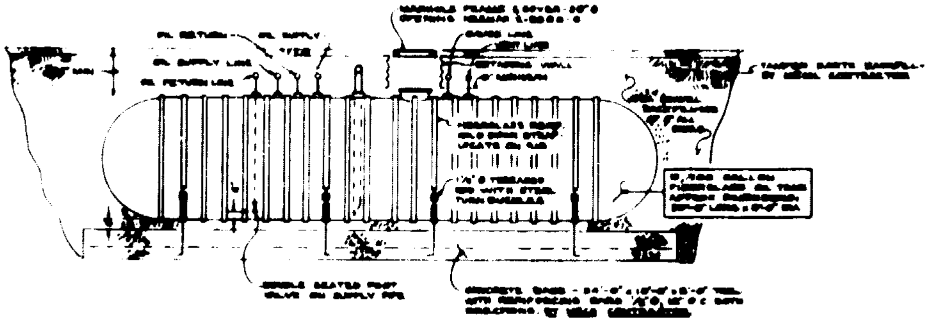

OIL STORAGE TANK

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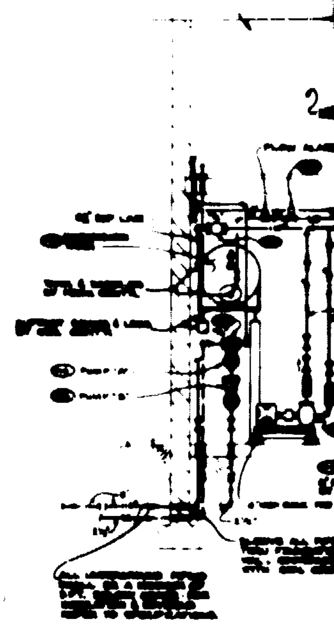
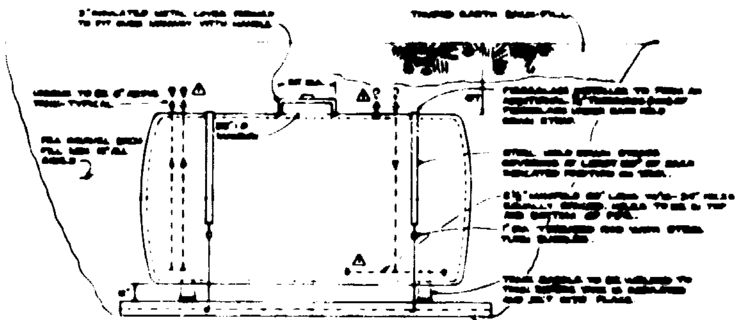
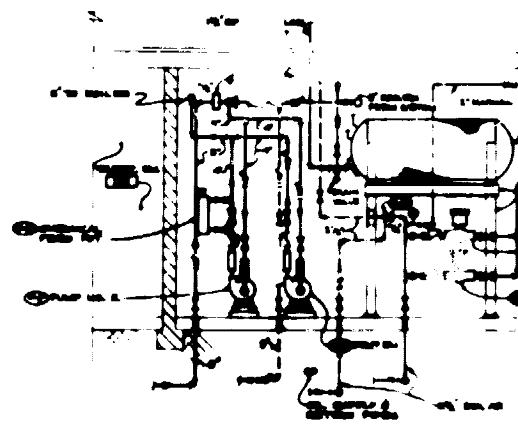




GENERAL NOTES

SOLAR HOT WATER STORAGE TANK



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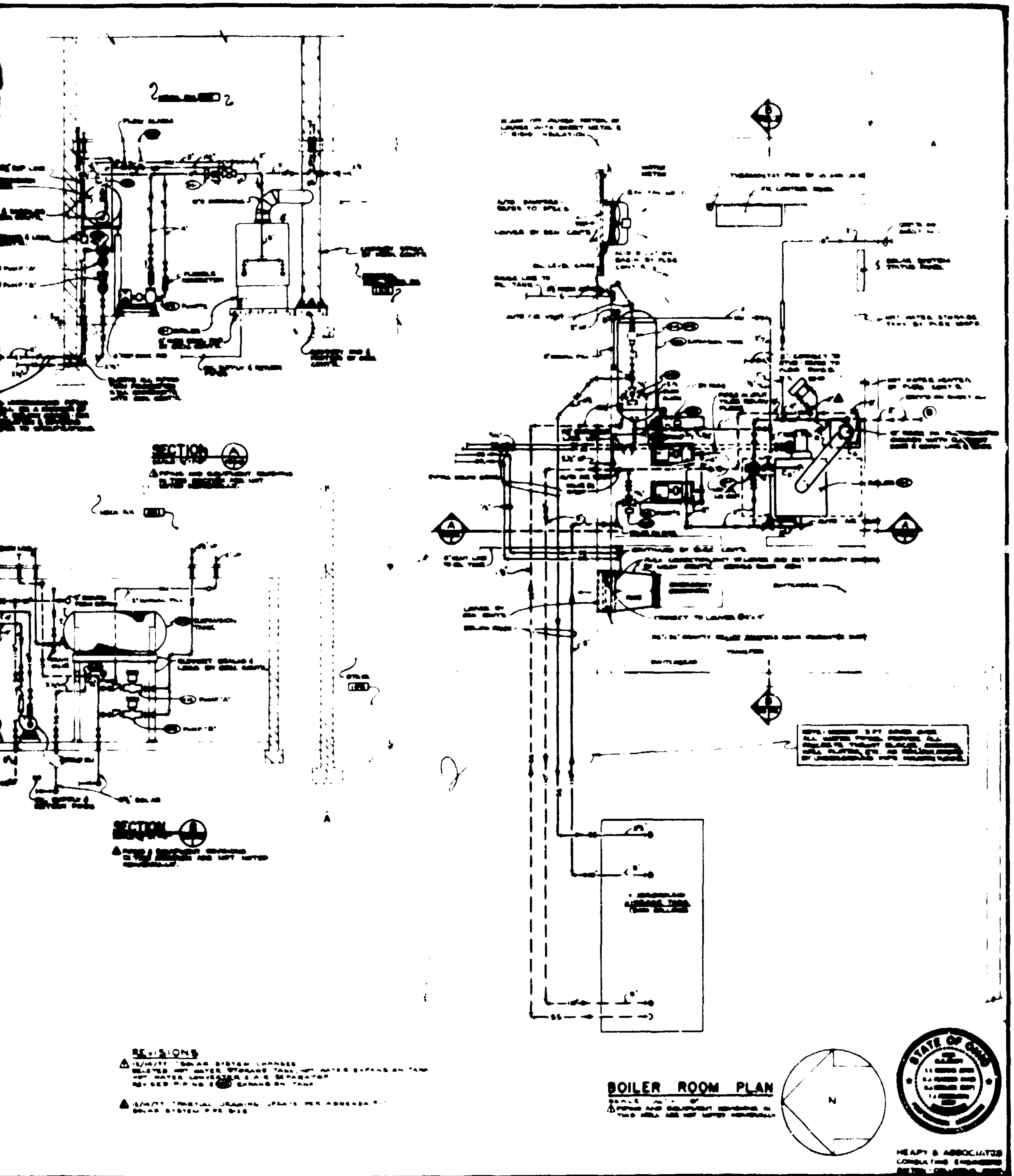

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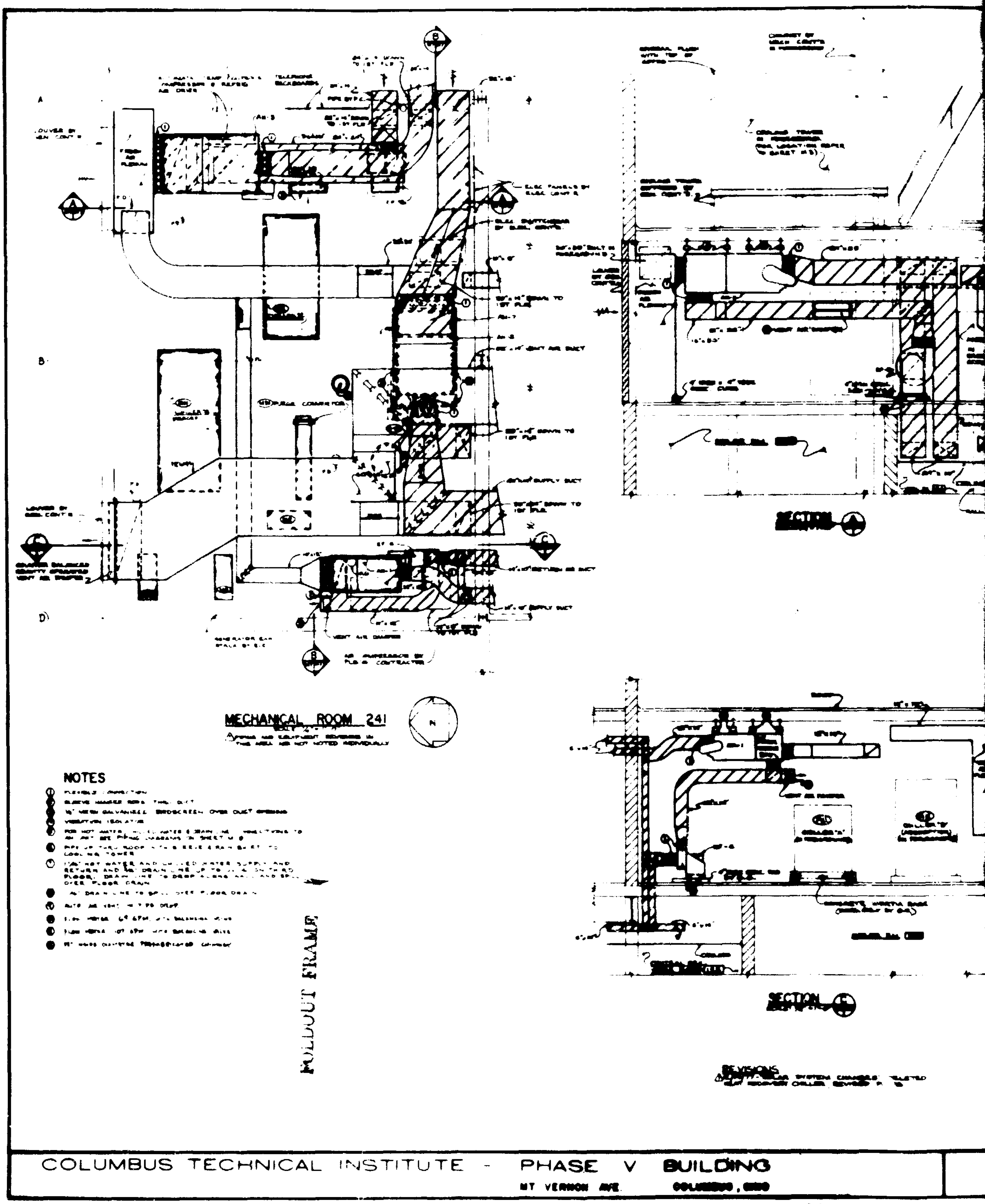
OHIO

BOILER ROOM

COMM NO 7605

McDONALD, CASSELL & BASSETT
ARCHITECTS

M-5



MECHANICAL ROOM 241
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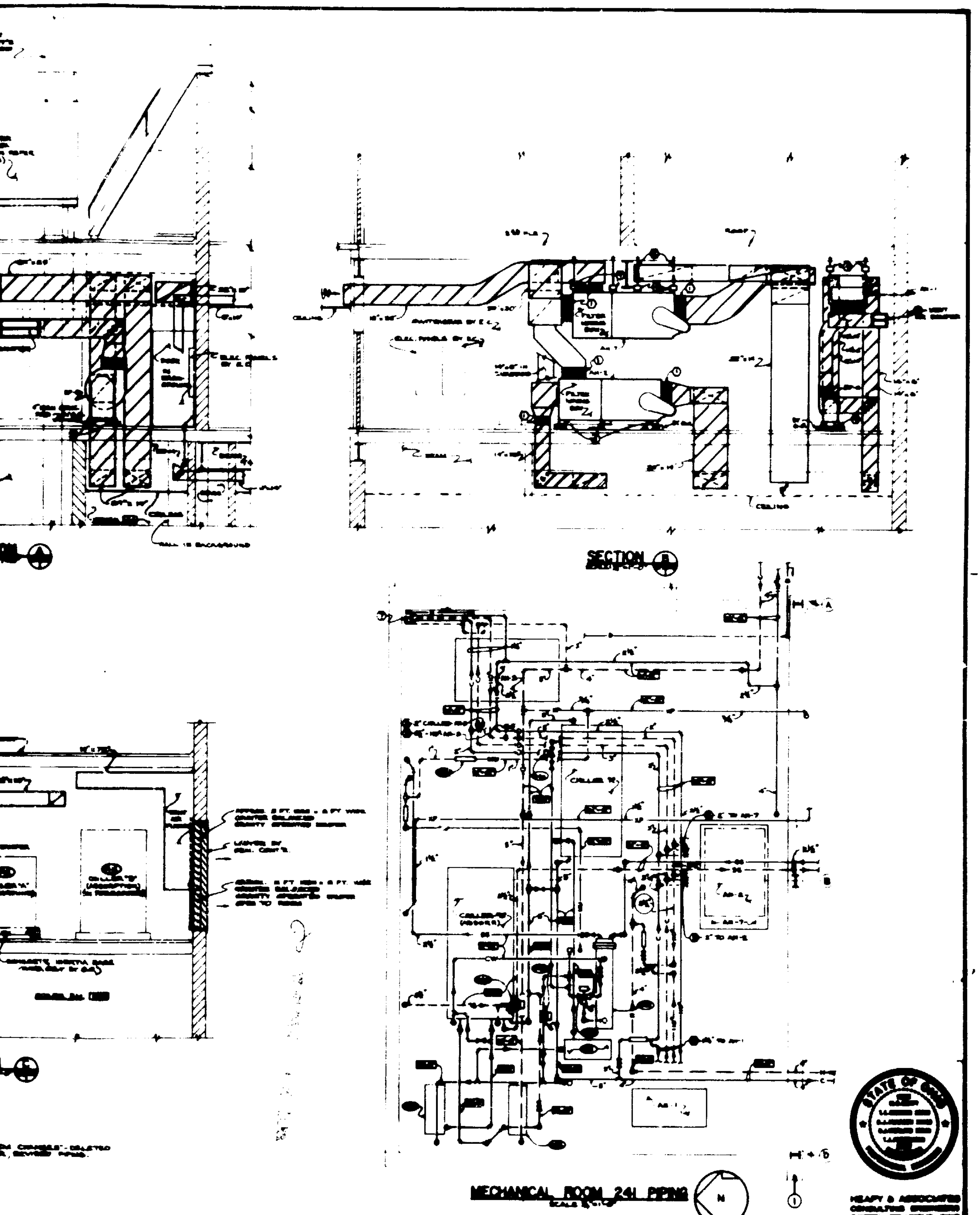

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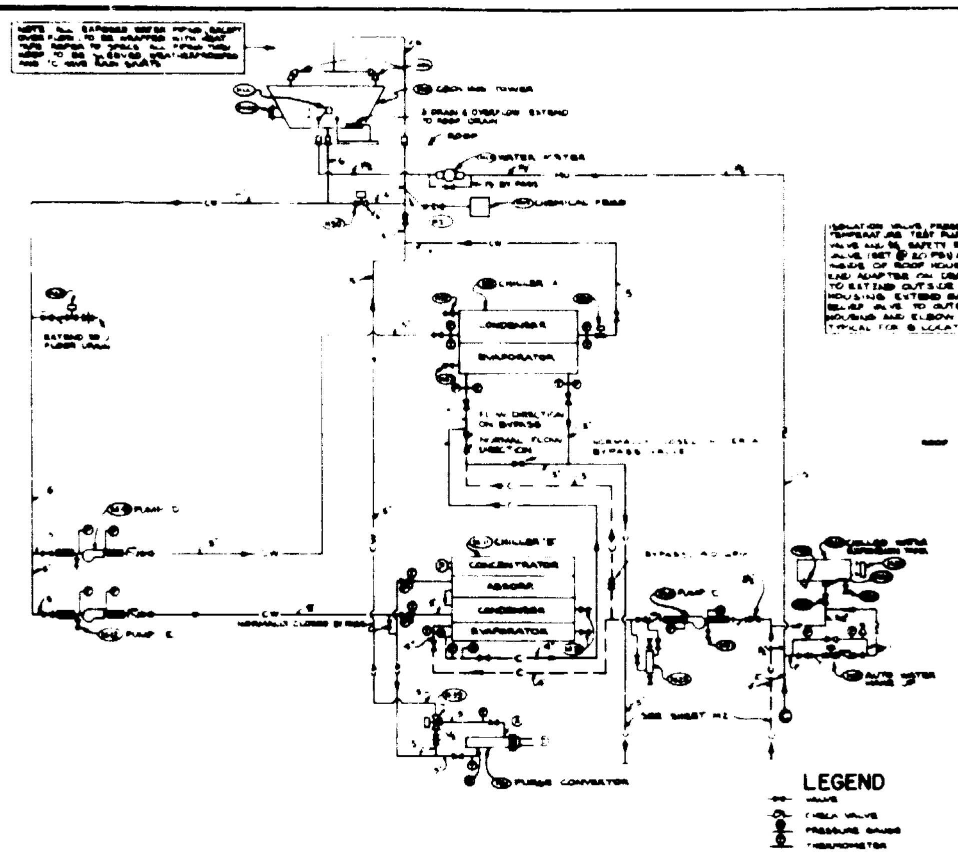

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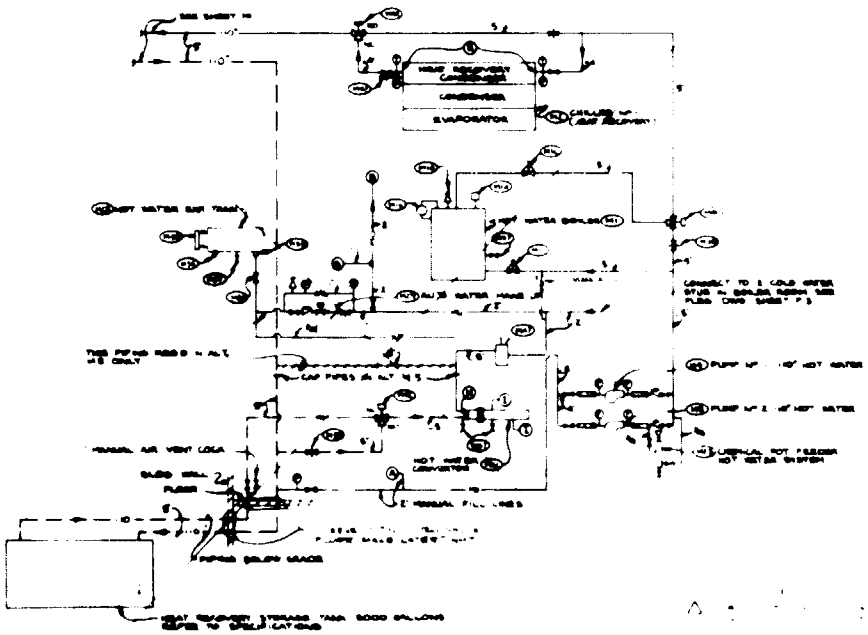

HOT WATER SYSTEM SCHEMATIC

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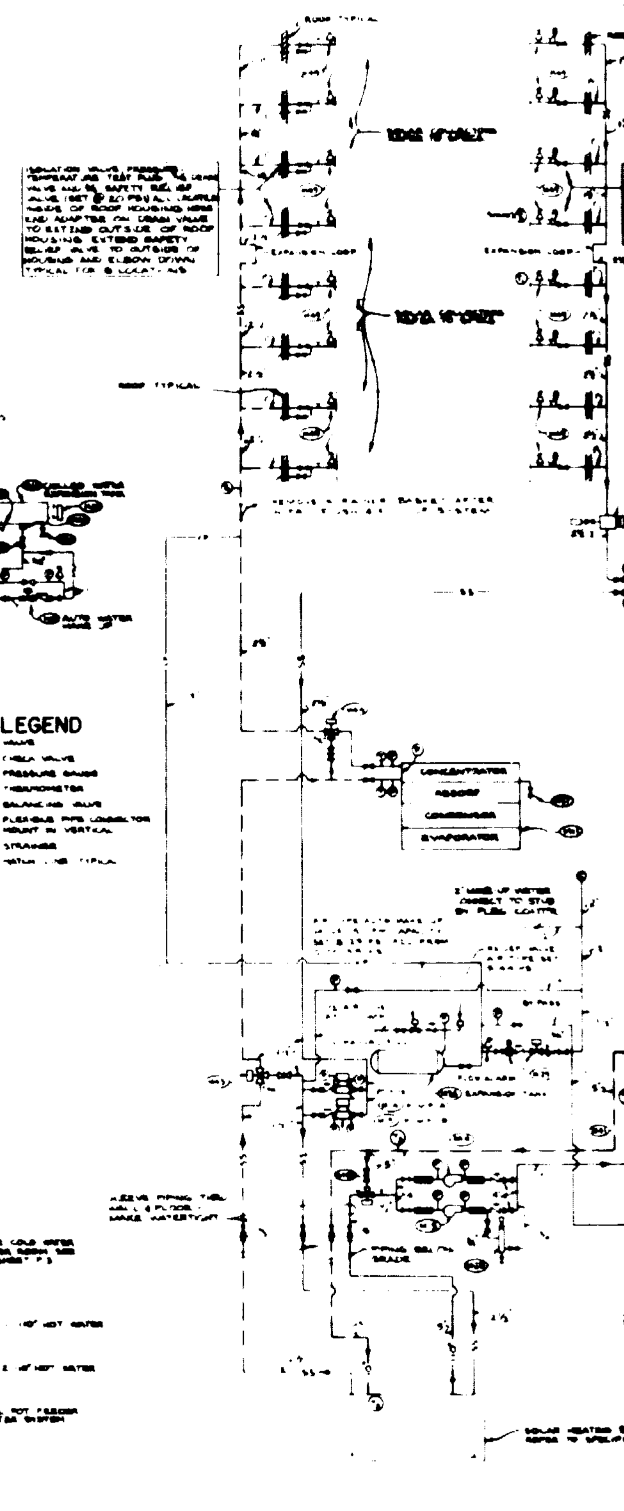

SOLAR HEATING SYSTEM SCH

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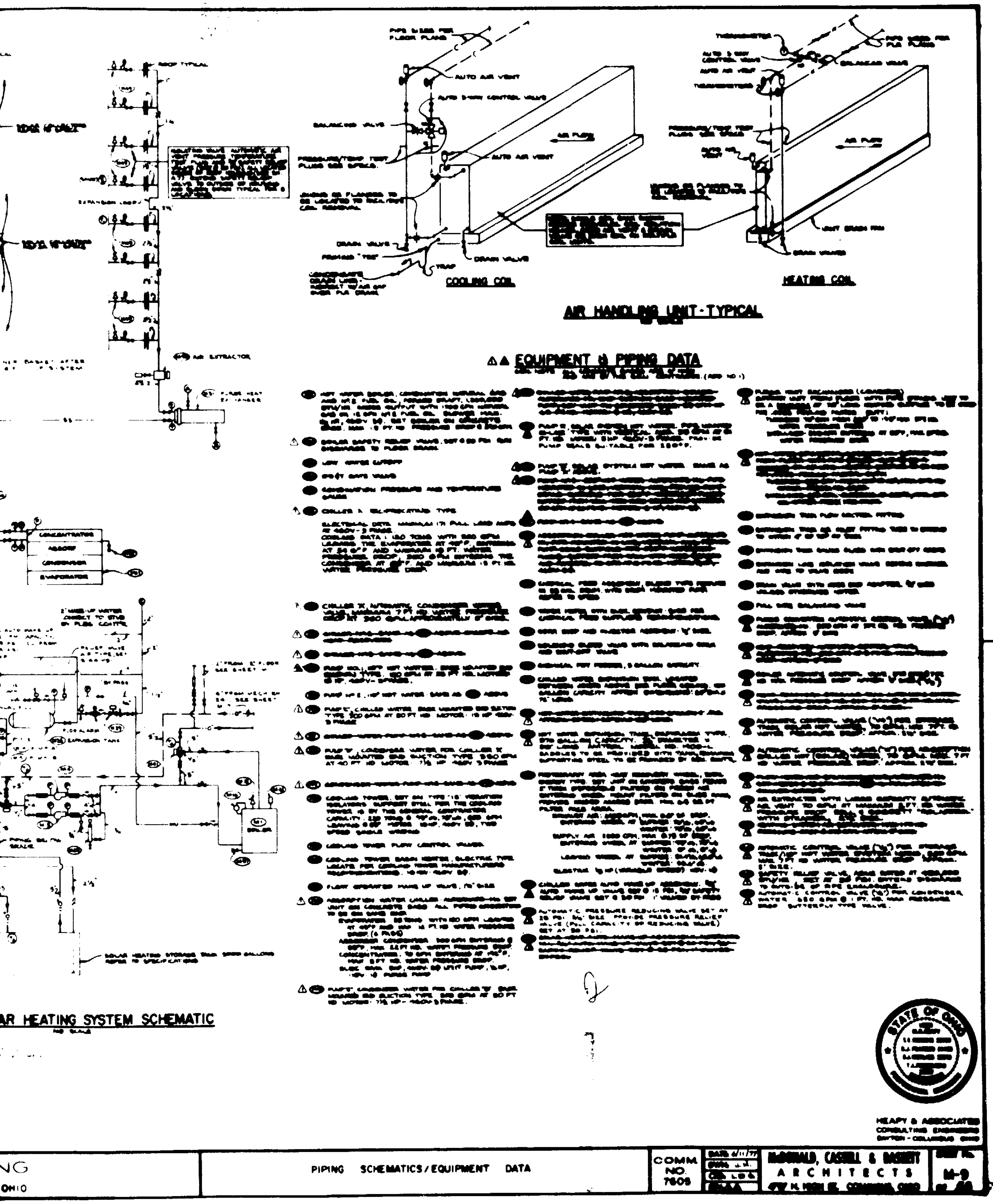
AUTO AIR VENT
DRAIN VALVE
COOLING COIL
HEATING COIL
AIR HANDLING UNIT - TYPICAL
EQUIPMENT & PIPING DATA
AIR EXTRACTOR
CONCENTRATOR
ABSORBER
CONDENSER
EVAPORATOR
EXPANSION TANK
BOILER
AR HEATING SYSTEM SCHEMATIC
NO SCALE
HEAPY & ASSOCIATES
CONSULTING ENGINEERS
DAYTON - COLUMBUS OHIO
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PIPING SCHEMATICS / EQUIPMENT DATA
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McDONALD, CASSELL & BASSETT
ARCHITECTS
M-9

APPENDIX B

SUNPAK^{TM} SOLAR COLLECTOR INSTALLATION, SERVICE, AND OPERATING MANUAL

OWENS-ILLINOIS

SUNPAK™ SOLAR COLLECTOR

INSTALLATION, SERVICE AND OPERATING MANUAL

SOLAR ENERGY PRODUCTS GROUP

FOREWORD

This manual is intended to serve both as a guide to installation procedures and as a means of understanding the basis of solar-collector operation and maintenance.

Those persons charged with understanding and operating the collector system should read and understand the entire manual.

Those persons concerned only with installation of hardware will find essentially all the necessary information in Section 2, Installation Procedure, and in the accompanying Figures and Drawings.

Each specific SUNPAK^{TM} application will be somewhat unique as a result of small differences in circumstances of installation and use. The manual is valid for the majority of these circumstances. The manufacturer should be contacted for recommendations if the customer feels his installation may be atypical in any way.

TABLE OF CONTENTS

IMPORTANT

Please see pages 7, 12, and 14 for safety information

1.0 General Description

1.1 Physical Dimensions

The standard SUNPAK^{TM} module consists of 24 individual collector tubes manifolded together as shown in Figure 5.1. A nominal gross area of 4'x 8' is occupied by the assembled module. The effective collection area of the standard SUNPAK^{TM} module is 27.4 square feet. It is the latter area (27.4 ft^2) that is used as the basis for describing collector performance and in quoting collector array prices.

A typical module weighs about 110 pounds (dry) and will contain about 9 gallons of fluid (water preferred) when filled. The resulting collector load is approximately 4 lb/ft^2 dry and 7 lb/ft^2 water filled.

1.2 Materials and Parts

The glass components are made with Owens-Illinois KG-33 (KIMAX^{R}) borosilicate glass to provide strength, optical clarity, and thermal shock resistance. The fluid passageways inside the manifold are copper. All internal copper connections are hard soldered. High temperature silicone rubber "O"-rings and grommets are used for seals. The copper cup assemblies and internal headers are encased in a molded urethane foam which serves as an insulating support structure. The urethane foam is sheathed in a rigid shell of fiberglass reinforced polyester resin. The materials have been chosen to resist damage to the collector by stagnation temperatures which may rise as high as 650^{o} F in an unfilled collector exposed to the sun.

A complete parts list appears in Table 1.

1.3 Fluid Flow

1.3.1 Collector Fluid Type

Water is the preferred heat transfer fluid due to its low cost and good thermal performance. The low loss property of the SUNPAK^{TM} collector makes use of water practical even in cold climates. The use of other fluids such as glycol solutions is also possible, but rarely necessary. Questions regarding fluid selection should be reviewed with the manufacturer in light of the specific application.

1.3.2 Fluid Flow Path

The SUNPAK^{TM} manifold is designed to deliver water in a serpentine series flow pattern to its 24 tubes. This is accomplished with the use of the standard 8 mm O.D. or optional 11 mm O.D. feeder tubes which channel water to and from the closed end of each collector tube. Figures 5.2A, 5.2B, and 5.2C illustrate the flow pattern. In a multi-module collector array, the individual modules are interconnected in parallel flow arrangement.

1.3.3 Collector Fill Flow Rates

Fluid flow rate during filling must be above a certain minimum value in order to prevent two phase flow in the feeder tubes and the resulting possibility of air entrapment. For the 8 mm standard feeder tubes, a minimum fill rate of 0.3 gpm/module is recommended with the optimum rate being 0.4-0.5 gpm/module. The 11 mm optional feeder tubes require a minimum fill rate of 0.6 gpm/module with 0.7-0.8 gpm/module being optimum. See Section 3.1 for details.

1.3.4 Collector Operating Flow Rates

Efficiency of energy transfer to the collector fluid will be affected by fluid flow rate. For the 8 mm standard feeder tubes, a minimum operating flow rate of 0.25 gpm/module is recommended and a flow rate of 0.3 gpm/module is considered to be near optimum. The 11 mm optional feeder tubes require a minimum operating flow rate of about 0.5 gpm/module with 0.6 gpm/module being optimum.

1.4 Installation Overview

1.4.1 General Description

The collector has been designed to allow easy installation. Heavy lifting equipment is not necessary as long as there is sufficient access to allow components to be carried to the mounting surface. Each component can be easily lifted by one man. After manifolds and brackets are mounted, collector tubes are simply inserted into their "O"-ring seals at the manifolds. Plastic end caps with adjusting screws are used at the closed ends of the tubes to hold them in place against hydraulic pressure in the operating system (see Figure 5.7). If a tube replacement is necessary, the plastic end cap is removed by loosening the adjusting screw and giving a quick twist. The tube can then be removed from its seal and a new one inserted.

1.4.2 Installation Manpower

The installation procedure is quite simple and requires a minimum of tools (see Table II). Although specific systems differ somewhat, a typical 100 ft^2 array, not including SUNPAK™ reflectors (see Section 1.4.6), could be installed with about one man-day of effort. Inclusion of the reflector elements in the installation of a new system would increase the installation time for the 100 ft^2 array to about two man-days of effort. Provision of proper tools, carpenters' aprons for carrying small parts, and efficient layout of the parts inventories to avoid long carrying distances will all serve to minimize installation time. A five-man crew seems to be optimum with three men on the collector hardware installation and two helpers to maintain an uninterrupted flow of parts.

1.4.3 Collector Manifold Arrangement

The manifold is designed with internal nominal 1-inch I.D. copper header pipes. Adjacent manifolds are coupled by a specially designed mechanical coupling included with the factory-supplied hardware. Additional couplings are available for connection of external piping to the manifold inlets and outlets. As many as 15 manifolds can be joined in a single row by interconnecting the internal headers. Longer arrays can be fabricated, but careful attention to flow arrangement and header pressure drops is necessary to assure balanced flow distribution to individual modules. Best flow distribution will result when the inlet and outlet of a given row of modules are at opposite ends of the array. Header pipe thermal expansion is taken up by the mechanical header couplings.

1.4.4 Mounting Surface

The collector is designed to mount on a tilted support surface provided by the customer. This can be a sloping roof or a sawtooth structure on a flat roof. The plane in which manifold and end brackets are mounted should not deviate from flatness by more than 1/4" along any 4' length. More pronounced irregularities, especially along the length of a manifold, will require the use of shims to provide a flat surface to assure proper tube and manifold alignment.

When the collector is mounted on a watertight surface, a commonly employed technique to minimize roof penetrations is the mounting of horizontal members on the roof exterior to which the collector brackets can be attached. The horizontal members may be treated 2" x 6" lumber or galvanized metal channels which are blocked up to allow water drainage. Roof penetrations at the blocking should be flashed or caulked for watertightness.

1.4.5 Diffuse Reflector Surface

Collector modules can be mounted over one of two types of background reflectors; a flat diffuse reflector, or a shaped (cylindrical) non-imaging specular reflector. For best results with the diffuse reflector, the surface should have a non-glossy, reflective nature such as flat white paint. A surface which tends to be self-cleaning with rain water would be most desirable.

Several diffuse reflector materials have been tested for reflectance. Those showing satisfactory reflectance included white vertical aluminum siding, white aluminum shingles, and white roof paint applied over asphalt rolled roofing. White exterior paint over plywood gives satisfactory reflectance for up to a year which might be acceptable for a small test stand, but this approach does not offer a long-life background needed for a permanent installation.

1.4.6 SUNPAK™ Shaped Specular Reflector

The SUNPAK™ Shaped Specular Reflector (SSR) is shipped ready-for-mounting by the customer using the spring tube clips and interlocking tabs on the reflector elements (see Drawing ED-1). This mounting system assures proper reflector alignment and structural integrity to withstand wind and snow loading.

1.4.7 Mounting Surface Tilt Angle

The angle of tilt of the support surface depends upon several factors which influence the matching of collector output with load requirements over the duration of the operating year. In general, a winter heating load is best satisfied with a south-facing array tilted at an angle of the latitude plus 10-20 degrees. A constant annual load such as domestic hot water would use a tilt approximately equal to the latitude. A load which peaks in the summertime would use a tilt equal to the latitude minus 10-20 degrees. Collector output is not very sensitive to deviations of a few degrees from the optumum tilt angle.

1.4.8 Special Considerations for Low Tilt Angle

Generally, the collector will be mounted at a tilt ranging from 30 to 70 degrees from horizontal. Tilt angles of less than 30 degrees will require special consideration of air clearing during collector filling. Information can be obtained from the manufacturer.

1.4.9 Mounting Surface Structural Integrity

The SUNPAK™ collector module and shaped reflector attachment are designed to withstand wind, snow, and ice loadings normally encountered in service. It is the responsibility of the customer to insure that the mounting surface to which the collector is attached has the required structural integrity to support the filled collector array under normally anticipated conditions. It should be noted that at recommended collector operating pressures of 30 psi or less, hydraulic pressure in the tubes will yield a resultant force at each mounting bracket attached to the surface. Maximum forces on the mounting surface are on the order of 30 lb. (downward) at each end bracket and 40 lb. (upward) at each center bracket. In long collector array designs, careful attention should be paid to the deflection characteristics of the support structure under wind loading. Further information can be obtained from the manufacturer.

2.0 Installation Procedure

2.1 Installation Sequence and Layout

2.1.1 Sequence

The general sequence of collector installation is as follows:

a. chalkline layout of mounting surface reference lines;
b. layout and mount manifold center brackets;
c. square and mount manifolds and mechanical header couplings;
d. square and mount tube end supports;
e. tighten support tie rods between manifolds and end supports;
f. install feeder and collector tubes;
g. connect external piping and leak check;
h. install manifold connector covers;
i. secure manifold connector covers and end caps.

The details of each installation will be somewhat different. The manufacturer's field service personnel have accumulated a good deal of experience and can be relied upon to prepare local installation crews and provide time-saving hints. The customer should not hesitate to call upon this experience either in the field or by phone or mail to the manufacturer's office directed to the responsible Project Manager.

2.1.2 Layout (Figures 5.1 and 5.4 and Drawings ED-1 and ED-2)

A single module will occupy a space of 4 feet wide and 8 feet tall. Provision should be made for minimum length runs of external piping at the end of an array of modules and for the manifold end caps which project about six inches beyond the ends of the array. Provision should also be made for removal of tubes during servicing which will require a minimum of 3" of clearance at the ends of the 8' module dimension. If the total array consists of several parallel rows of modules, then access must be provided between rows for servicing any point in the array.

A chalkline is first made to fix the centerline of the manifolds. Two additional chalklines are then laid out parallel to the first and lying 46' +1/8", -0" above and below the manifold centerline. These lines mark the centerlines of the tube end support mounting spacer holes. A perpendicular chalkline is made at the starting end of the array to mark the end of the first module. Additional perpendicular lines may be made at 4' intervals down the row to mark the space occupied by each module. Intervals should be measured along a stationary steel tape to avoid accumulated measurement error.

2.2 Manifold Center Brackets, Part SK-2852, Figs. 5.4, 5.5, and Drawing ED-1

Manifolds are mounted with 3 center brackets per module which are fastened to the mounting surface on the manifold centerline chalkline. The first bracket of the first module is located 8" inboard from the first perpendicular reference chalkline marking the end of the first module. Remaining center brackets in the row are secured at 16" intervals. The 16" tolerance is approximately equal to ± 1/16" and should be done with a stationary steel tape to prevent accumulated measurement error. The center brackets are fastened to the mounting surface with appropriate customer-supplied fasteners.

2.3 Squaring and Mounting Manifolds, Part SK-5155, Figs. 5.5, 5.6, and Drawing ED-1

Field experience has shown that careful aligrment of the manifolds at this point can result in optimum alignment of all components in the array. It should be noted that manifolds must be positioned on the center brackets with the "T" marking on the bottom mounting brackets facing the upslope side of the mounting surface. The manifold nameplate should be on the downslope side of the surface.

At this point, both the first and last manifold of each row of modules should be lowered onto the center brackets and made hand tight using the threaded end of the support rod (SK-2851) and the locknut/washer assembly. Use of two washers in this assembly may help to avoid deformation of the brackets due to inadvertent over tightening. Both manifolds should be made perfectly square and level in all directions using a steel square, steel scale, and level. Support rods are then tightened to hold manifolds firmly.

Mounting of the intermediate manifolds is made easier by temporarily locating a taut steel wire (use a turnbuckle) about 1" above the two end manifolds and extending the full length of the collector array between these manifolds. After making sure that this wire is perfectly straight and level, all intermediate manifolds should have the same relationship to the wire as the two end manifolds already mounted.

The remaining manifolds can now be lowered into place one at a time being sure to attach the floating mechanical coupling (SK-3047) at each header connection. When manifolds are properly aligned and secured by the support rods, a gap of 1/8" should exist between ends of adjoining header pipes. This gap and the coupling are used to take up thermal expansion of the headers. No soldering is necessary within the array. Mechanical couplings can be tightened at this time.

2.4 Tube End Supports, Part SK-2848, Figs. 5.4, 5.5, and Drawings ED-1 and ED-2

The aluminum tube end supports are now mounted using the "Z" shaped mounting spacers (SK-2880). The horizontal chalklines at 46" +1/8, -0 serve as the centerlines for the mounting holes of the "Z" brackets. The

first pair of brackets will be located opposite one another at a point 2" inboard from the first perpendicular reference chalkline marking the end of the first module. The second pair of brackets will be located 46" inboard from the first pair. Intermediate brackets will be mounted at 48" intervals. Brackets for the last module in a row will again have a 46" separation as did those for the first module. A stationary steel tape should be used to lay out these mounting holes since accumulated measurement error will result in collector tubes not being perpendicular to the manifolds. This could lead to sealing problems.

If not already done, the tube end supports and "Z" mounting spacers should be fastened together. Working at the first module of the row, these assemblies should be placed onto the support rods and held in position at the mounting holes to check the squareness of the support rods to the manifolds and the end supports. If square, the rubber pads (SK-2875) can be placed beneath the feet of the mounting spacers and the spacer/end support assemblies can be mounted for all modules in the row. A spot check of the squareness of the support rods in the row is advisable.

The butt joints between successive tube end support channels are made with a simple clamp arrangement using the clips (SK-2870) and a bolt (SK-5318) and nut (SK-5316). Since no clips are used on the first and last brackets of a row (no butt joints at these locations), a small shim spacer (SK-2989) is provided to maintain constant collector tube height. The shim is inserted between the tube end support and mounting spacer. Larger shims under the feet of the "Z" mounting spacers may be needed if the mounting surface is very irregular. Wherever penetrations are made directly into a roof structure, care should be taken to maintain the integrity of the roof.

The nuts holding the threaded support rods to the tube end support channels may now be made tight enough to adjust the distance between the inner face of the support channel and the flat side of the manifold to equal 41-1/2" - 41-5/8".

Manifold connector covers (SK-5419) should be fastened into place with the special fasteners (SK-5407).

2.5 Feeder Tube (SK-4920) and Collector Tube (SK-3092) Installation, Fig. 5.7 and Drawing ED-1

!!SAFETY GLASSES AND GLOVES SHOULD BE WORN!!

The feeder tubes form a continuous fluid channel when the flared ends are snapped into place in the manifold grommets (SK-4921). Installation procedures are identical for the standard 8 mm feeder tubes and the optional 11 mm feeder tubes. Care should be exercised in properly sealing the tubes in the grommets. Do not use any petroleum-based lubricants on the silicone rubber parts. If some lubrication is required during installation, only a common soap solution in water or ethylene glycol should be used. Silicone rubber can become brittle and crack in a short time after contact with petroleum compounds.

Before actually inserting the feeder tubes, a check should be made of every collector tube opening in every manifold in the array to be certain that grommets, end seals, and "O"-rings are in place and passageways are clear. It should also be confirmed that the protective carbon material is present on the non-flared ends of the feeder tubes. This assures that the collector tubes will not be damaged when slipped over the feeder tubes.

Do not walk on installed manifolds or tube end supports at any time. Supporting brackets were not designed to withstand such loading and improper collector tube and manifold alignment may result.

Ideally, sufficient access should exist between rows of modules to allow the feeder tubes and collector tubes to be installed separately as in Figure 5.7. If this is the case, all feeder tubes can be installed at this time. If insufficient access exists to insert the tubes from the ends of the tube end supports, then feeder and collector tubes must be installed together. Basically this involves placing the feeder tube into the collector tube and lowering both into the space between the manifold and tube end supports. The closed end of the collector tube is extended through the tube end support and the feeder tube is withdrawn slightly from the open end of the collector tube to allow seating of the flared end into the grommet.

Proper tube and manifold alignment will be assured if the following sequence of tube insertion is observed. This sequence is valid regardless of which method is used to place the feeder and collector tubes. Tubes 1 and 2 of the first manifold in the row of modules should be inserted and the support cup assemblies (SK-3048) put in place and made finger tight fixing the space between the flat side of the manifold and the end support channels at 41-1/2" - 41-5/8". (See Figure 5.2C for details of tube numbering sequence.) Nuts on the support rod outboard ends may have to be loosened. Tubes number 23 and 24 of the first module should then be installed in the same manner followed by the four tubes at the center of the manifold. By "playing" the adjusting screws of the support cups against the support rod nuts, the proper 41-1/2" - 41-5/8" dimension can be fixed and the nuts on the support rods given a final tightening. At no time should support cup adjusting screws be more than finger tight.

Remaining tubes in the first module can now be installed. Tubes for other modules in the row should be installed in the same sequence. It should be noted here that the optional shaped specular reflector element (SK-2988) should be installed as each tube is installed. Spring clips (SK-2987) and the interlocking reflector tabs are much easier to work with at this point.

2.6 External Piping To and From the Solar Collector

The piping connections to the collector may be made at either end of a bank. The top header, i.e., the pipe located furthest from the mounting surface, is the outlet header. The bottom pipe is the inlet header.

The connecting piping to each row of manifolds should be properly supported to prevent undue stress on the collector system. Expansion of external piping from the collector should be considered in this area. The headers within the collector manifold are compensated for expansion by the mechanical coupling. Support to the manifolds is not designed to cover the stresses that may be introduced by the connecting piping.

External piping may be joined to the manifold header pipes by a soldered connection, but extreme caution should be exercised to prevent damage to any of the soldered connections inside the manifold or the manifold insulation. An electrical resistance soldering tool is recommended, but a torch can be used if heat shields are employed to protect manifold insulation. A solder of 95% tin and 5% antimony is recommended.

A preferred alternative is the connection of external piping using the positive restraint coupling (SK-4253) as shown in Drawing ED-2. This avoids all soldering and can also be used in conjunction with the termination adaptor (SK-5319) for header pipe termination.

Vent valves near the inlet and outlet connections are recommended for several purposes. These parts can be used as air vents when the system is filled or drained. These valves may be manual or automatic depending on desired operation conditions. In an emergency no flow condition, the steam may be vented through these valves to protect the system from undue thermal and pressure conditions.

The maximum recommended operating pressure of the solar collector row is 30 psig. The recommended design is to provide for a pressure relief valve of 30 psig or less in the outlet header line to vent the collector in an emergency condition. It is absolutely essential that no type of shutoff valve be located between the collector and the relief valve. Such a valve could be accidentally closed and eliminate overpressure protection. The inlet of the collector should be maintained below 30 psig and can be accomplished with a pressure regulator in the system. Each pressure relief valve should be vented properly to insure that steam and water are diverted safely. A pressure relief valve should be provided to each row of manifolds. For multi-manifolded rows, each row which can be isolated from the system <u>must</u> have a safety relief valve.

2.7 Leak Detection

The collector row should be checked for leaks at the coupling between modules and at the connecting piping. Next, the "O"-ring seal area should be checked for leakage. Leak testing can be with either air or water. Water is the preferred method and can be used by pressurization of the system not to exceed 30 psig. In some systems or situations, it may be desirable to use air to check for leaks. In these cases, pressurization with low pressure air (~5 psi) and a soap solution is a convenient way to find leaks before a system is water filled. The collector should not be pressurized over 10 psi with air due to the potential hazard of flying glass if a tube would be broken. Note that air testing is not recommended during a bright, clear day. Evenings or nights are suggested to reduce pressure-volume changes of air as it is heated in a closed system.

2.8 End Cap Attachment, Part SK-5153, Drawing ED-2

After leak testing, the insulating end caps can be cut as necessary to make provision for the connecting piping. The caps should fit as closely as possible to the piping to minimize heat losses. The caps are held in place by the special fasteners (SK-5407) which permit access to this location for system servicing.

2.9 SUNPAK™ Test Module Package - Special Note

Purchasers of the two-module test array package will also receive this Installation and Operation Manual, and should become thoroughly familiar with all information presented even though the test array is of small size. All installation procedures and modes of operation are identical for large arrays and the small test array. Some time might be saved, however, by taking note of the following facts about the test array:

a. Depending on the nature of the mounting surface and physical access, the entire array could be assembled in the shop and carried to the final location.

b. Wherever assembly is done, use of reference chalklines is still recommended, but the use of a taut steel wire is not necessary in aligning the two manifolds (see Section 2.3).

c. Since both manifolds are the "ends" of a row, the spacing between the mounting holes of the "Z" shaped mounting spacers will be 46" for both modules (see Section 2.4).

d. If more convenient, external piping connections for the inlet and outlet header pipes may be at the same end of the two module array. Any flow maldistribution should be negligible for such a short array (see Section 1.4.3).

e. The mounting surface need not necessarily be constructed for long term durability. Exterior grade plywood with a suitable finish is acceptable (see Section 1.4.5).

f. Since many test modules may be run without energy storage facilities and without sophisticated control logic, it may be advisable to make special provisions to drain the solar loop when necessary due to severely cold weather. This must be accomplished manually in the test module array by removing the first inlet tube of each module (tube #1) and all the even numbered tubes in the module (see Figure 5.2C for tube numbering sequence).

g. During periods of high insolation and no collector fluid flow, the possibility of collector boilout can be easily avoided by temporarily shading the test module with a suitable opaque cover. The collector modules need not be drained if this step is taken.

h. The structural integrity of the mounting surface is equally important for test modules and large sized arrays. Even though the test installation may be temporary, the mounting surface must be sound (see Sections 1.4.4-1.4.9).

3.0 Recommended Operating Procedures

3.' Filling

The internal parts of the SUNPAK™ solar collector will approach temperatures in excess of 600° F while standing in bright sunlight. While the SUNPAK™ collector has been constructed with low expansion glass, filling the collector during midday portions of a bright day are not recommended. Filling a collector in a bright sun could cause damage due to thermal shock. Introduction of a fluid into a hot tube could also result in the initial slug of fluid leaving the collector to be a mixture of hot water and steam. The outlet from the collector on initial fill should be properly vented. The recommended procedure to avoid steam generation and potential thermal shock of the equipment is to fill in the early morning so that a high stagnation temperature is not reached. Filling should not be attempted after 9:00 A.M., and is best carried out less than one hour after sunrise.

The invidivual modules of a collector array are connected in a parallel fluid flow pattern. The fluid flow rate during filling must be sufficient to cause all modules in the array to fill uniformly and to prevent two-phase flow in the feeder tubes which could lead to air entrapment. Air entrapment can cause one or more modules to cease flowing if the back pressure of the air lock is greater than the pressure drop offered by neighboring modules. Air locks may also be encountered when a partially filled array is refilled or whenever air is introduced into a filled array such as when the piping is drained for repairs. The piping system should be designed to minimize the introduction of air into the array during normal operation.

Air entrapment during collector filling can be avoided through the use of the following flow rate guidelines. For the standard 8 mm feeder tubes, a minimum fill rate of 0.3 gpm/module is recommended with optimum fill rates lying in the 0.4-0.5 gpm/module range. For the optional 11 mm feeder tubes, a minimum fill rate of 0.6 gpm/module should be used with 0.7-0.8 gpm/module being optimum.

IMPORTANT

The boiling out of a collector as a means of emptying the collector for shut-down is not recommended. Under extreme insolation conditions, the collector could be damaged by thermal shock.

3.2 Operating Flow Rates

The operating flow rates recommended for the SUNPAK™ collector module are a compromise between desired fluid temperature gain, energy requirements of the load, adequate flow distribution in the collector array, and fluid pumping costs. For most applications, the standard 8 mm O.D. feeder tubes provide adequate energy delivery with good fluid distribution and acceptable pressure drops across the array. Some load requirements, however, have demanded higher fluid flow rates. Larger feeder tubes of 11 mm O.D. have been added as an option to give higher flow rates at pressure drops across the array which are comparable to the smaller, standard feeder tubes at lower flow rates.

Figure 5.3 shows the pressure drop across a module as a function of fluid flow rate for both 8 mm and 11 mm feeder tubes. The flow characteristics of the collector are such that a pressure drop of 5 psi or more across the array will assure that distribution of flow to all modules in the array is uniform. As flow rates rise above the minimum needed for good fluid distribution, collector residence time is shortened and fluid temperature gain is reduced. It has been found that the optimum compromise flow rates for the SUNPAK™ collector are 0.3 gpm/module for 8 mm feeder tubes and 0.6 gpm/module for 11 mm feeder tubes.

3.3 Freeze Protection

The very low loss coefficient of the SUNPAK™ collector affords it excellent freeze protection. The collector will gain enough energy on even the cloudiest days to prevent freezing of the collector modules during daylight hours or through a below freezing night. Piping to and from the collector modules is, however, more vulnerable to freezing, especially under no-flow conditions. The length of such external piping runs should be minimized. It is recommended that all piping systems external to the collector be properly insulated to avoid the problem of freezing a line to the collector resulting in isolation of that element.

Temperature monitoring of the collector fluid is suggested and heat may be added at night to keep the solar loop from freezing. Where below freezing temperatures are particularly severe or prolonged, exposed piping to and from the array should be electrically traced and insulated. Under conditions of no fluid flow, it may be advisable to charge a sustained pulse of fluid to the array at about 4-hour intervals. This pulse can be drawn from storage and should be of sufficient duration to totally displace all fluid contained in the tubes, manifolds, and system piping (each module contains about 9 gallons of fluid).

The collector's tubular design tends to shed snow easily. Experience in Toledo has shown that even a nine-inch snow storm did not cover the array. However, if an array should become completely snow-covered such that no insolation could reach the collector, there could be a danger of freezing the array. To prevent this, the entire volume of water in the exposed solar loop should be exchanged with warm water at least once a day.

IMPORTANT

3.4 Maintenance and Safety

Extreme caution should be exercised when performing maintenance on the collector. Accidental breakage of a tube in a system operating under pressure at temperatures above 140° F could result in serious burns to personnel. Tubes should not be removed from an array during periods of bright sunlight if there is a possibility that the module being serviced could be air locked. This could lead to the release of pressurized steam, even though the inlet and outlet headers may be at atmospheric pressure.

Care should be exercised in handling partially filled tubes which may have reached elevated stagnation temperatures in the unfilled portion of the tube. Pouring water from the tube could cause flashing of the water as it contacts the high temperature region of the tube and in some cases this may result in breakage of the tube.

Personnel handling the evacuated collector tubes should wear gloves and safety glasses. This is standard procedure for any routine glass handling work. Failure of a tube due to rough handling results in an implosion and does not generate a serious problem due to flying glass.

The collector support structure should be designed to prevent harm to people or property from falling glass or hot heat transfer fluid in the event of failure of a glass tube or other collector part. If corrosive or toxic heat transfer fluids are used, provision should be made to conduct these fluids to a safe area in the event of collector failure. Safety relief valves protecting the collector against pressures greater than 30 psig should be vented to a safe area.

The collector tubes tend to be self cleaning in normal rainfall. However, if extended dry periods or other abnormal conditions cause an excessive covering of dirt on the collector, occasional hosing off is recommended. If performance is being measured with the aid of a pyranometer, the cover of the pyranometer should be kept clean at all times.

Under conditions of no fluid flow, high levels of insolation on a filled collector can rapidly lead to a boilout condition in the collector. The system should not be shut down for maintenance during bright sunlight hours unless absolutely necessary. If such a daylight shutdown is unavoidable, that portion of the system requiring service should be isolated from the remainder of the system and shut down. That portion of the system must then be drained down or adequately shaded from insolation. It is better to schedule no-flow types of maintenance for night hours or periods of low insolation when no draining or shading is needed.

Recommended spare parts should include 2% extra collector and feeder tubes. Required quantities of other expendable parts (gaskets, seals, etc.) will vary with the installation and can be recommended once the system characteristics are defined.

3.5 Monitoring Performance

Performance of the SUNPAK™ collector can be monitored by comparing the useful energy being gained by the collector to the insolation entering the plane of the collector. Consideration must be given to the residence time of the collector when determining heat gained. For example, a module operating with a 0.3 gpm flow rate will have a 30 minute residence time. To calculate the heat being gained, one would determine a ΔT by subtracting an inlet temperature from the outlet temperature which occurs 30 minutes later. This residence time would, of course, be different for other flow rates. Residence time can be estimated assuming plug flow and a 9 gal/module fluid capacity.

3.6 Technical Assistance

If additional information is desired, please contact the responsible manufacturer's Project Manager at the following address:

OWENS-ILLINOIS, INC.
Solar Energy Products Group
SUNPAK™ Program
P. O. Box 1035
Toledo, OH 43666

4.1 TABLE I

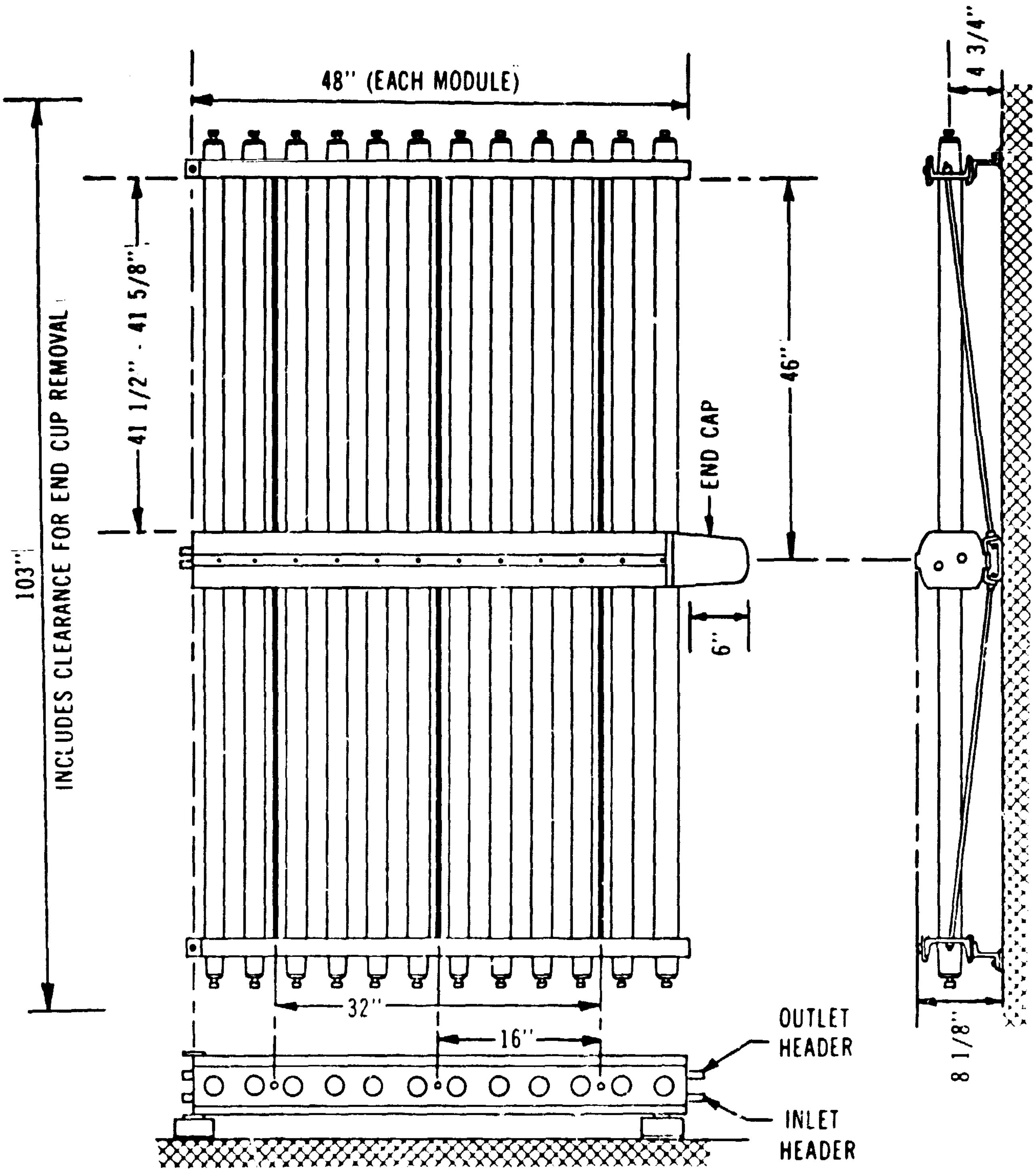
SUNPAK™ PARTS LIST

Number Required Per Module	Part Number	Part Identification
1	SK-5155-2	Standard Manifold (8 mm Feeder Tubes)
1	SK-5155-1	Optional Manifold (11 mm Feeder Tubes)
12	SK-4921-2	Standard Grommets (8 mm Feeder Tubes)
12	SK-4921-1	Optional Grommets (11 mm Feeder Tubes)
24	SK-4920-2	Standard Feeder Tubes (8 mm)
24	SK-4920-1	Optional Feeder Tubes (11 mm)
6	SK-2851	Support Rods
3	SK-2852	Manifold Center Brackets
2	SK-2848	Tube End Supports
4	SK-2870	Clips
2-4	SK-2875	Mounting Pads
2-4	SK-2880	Mounting Spacers
[illegible]-2	SK-2989	Shim Spacers
24	SK-3048	Support Cup Assemblies
24	SK-3092	Collector Tube Assemblies
2	SK-3047	Floating Tube Couplers
As Required	SK-4253	Positive Restraint Tube Couplers
As Required	SK-5319	Termination Adaptors
2 Per Junction	SK-5419	Manifold Connector Covers
4 Per Junction	SK-5407	Manifold Connector Cover Fasteners
1 Per End	SK-5153	End Caps
2 Per End	SK-5407	End Cap Fasteners
24	SK-2988	Optional Shaped Specular Reflectors

4.2 TABLE II

SUGGESTED INSTALLATION TOOL LIST

1. "Holster"-type tool pouch
2. Carpenter's apron for small parts
3. 1/4" ratchet socket drive
4. 1/4" x 6" drive extension
5. 5/16" deep well socket (1/4" drive)
6. 5/16" nut driver



48" (EACH MODULE)
103"
INCLUDES CLEARANCE FOR END CUP REMOVAL
41 1/2" - 41 5/8"
46"
END CAP
6"
32"
16"
OUTLET HEADER
INLET HEADER
4 3/4"
8 1/8"

Figure 5.1

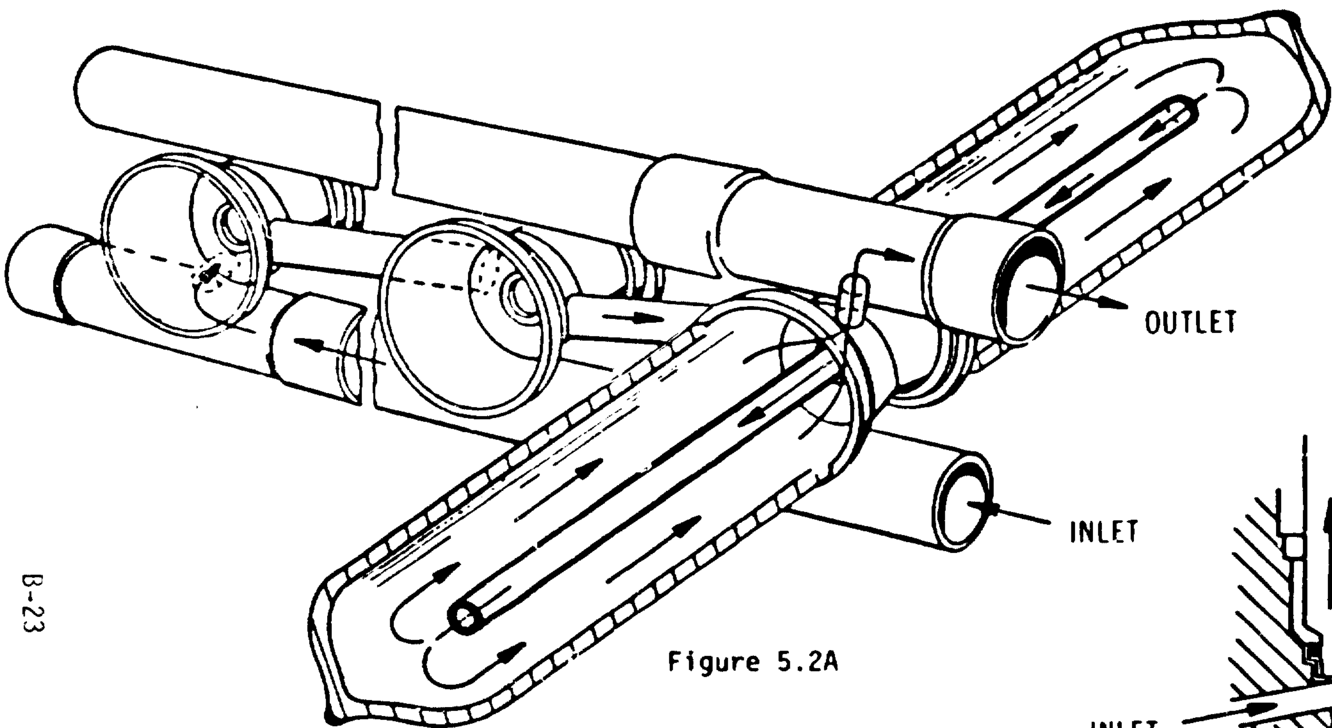


Figure 5.2A

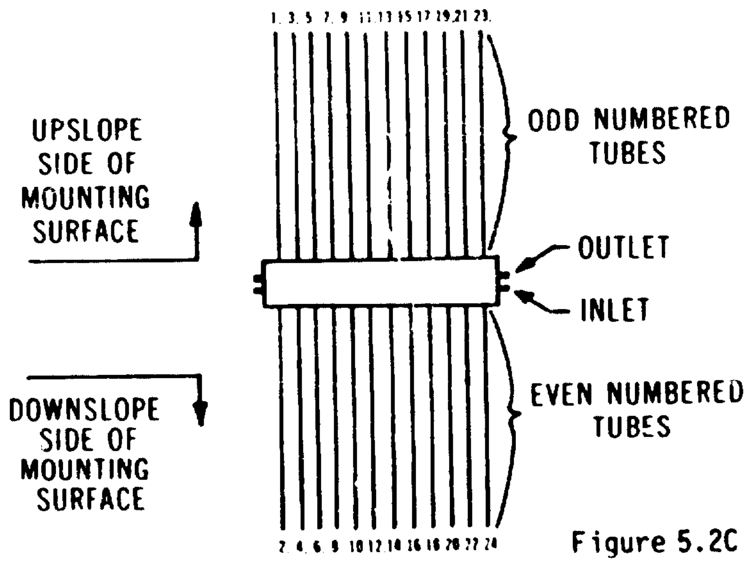


Figure 5.2C

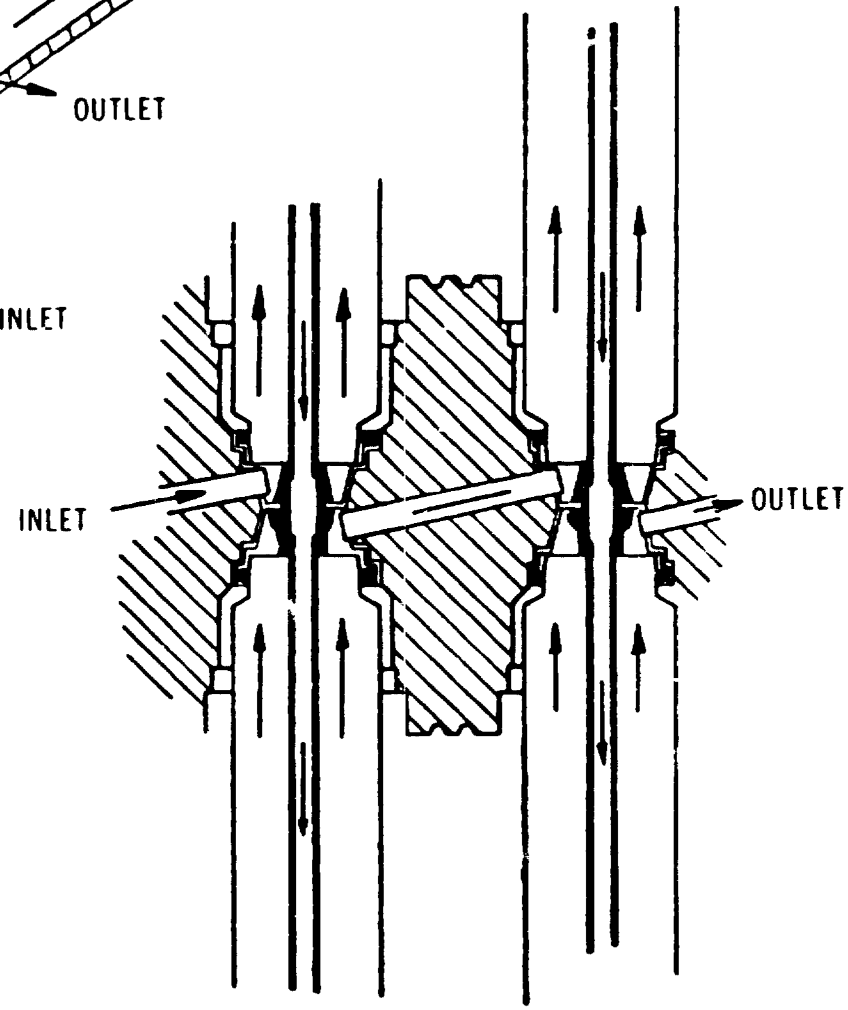


Figure 5.2B

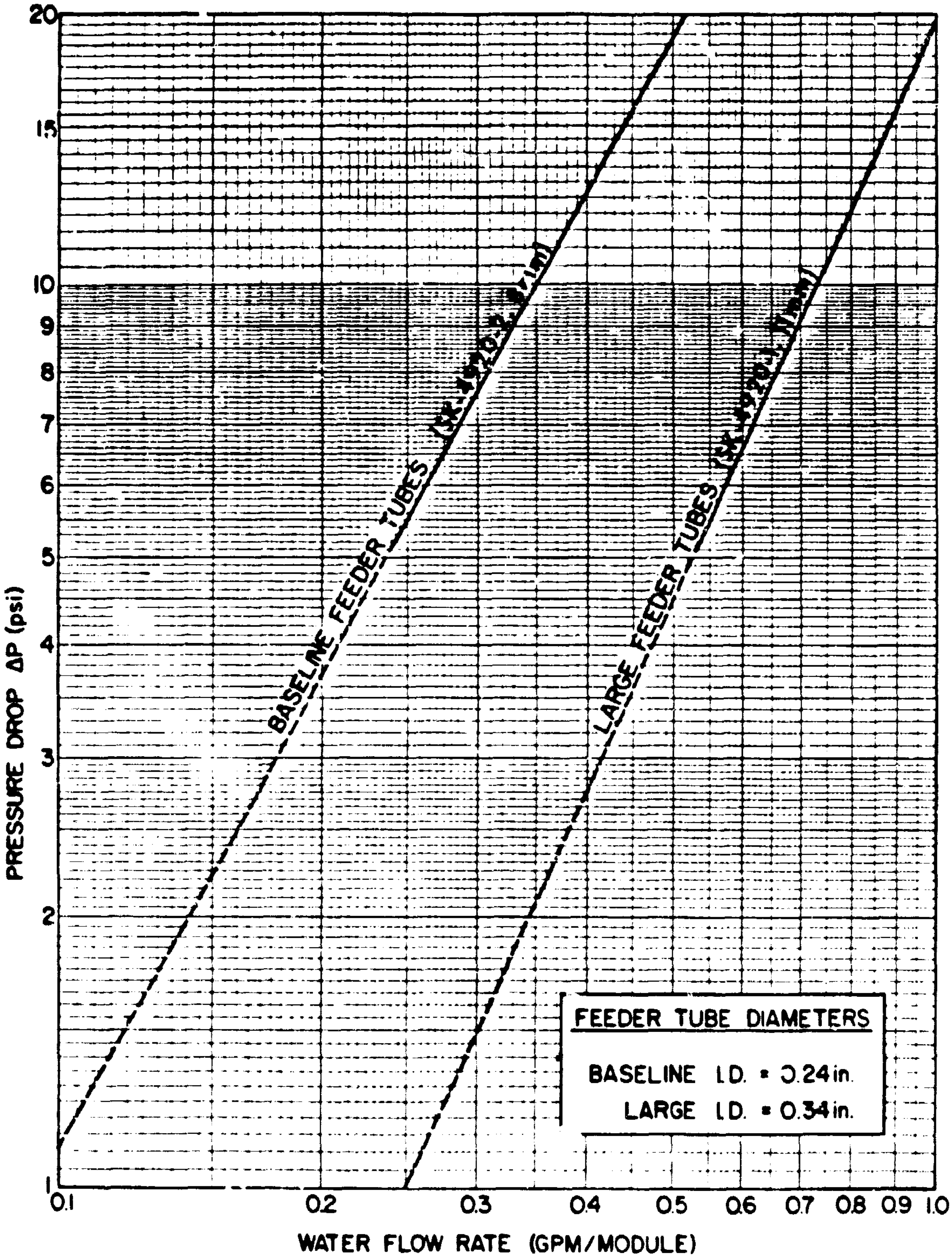


Figure 5.3

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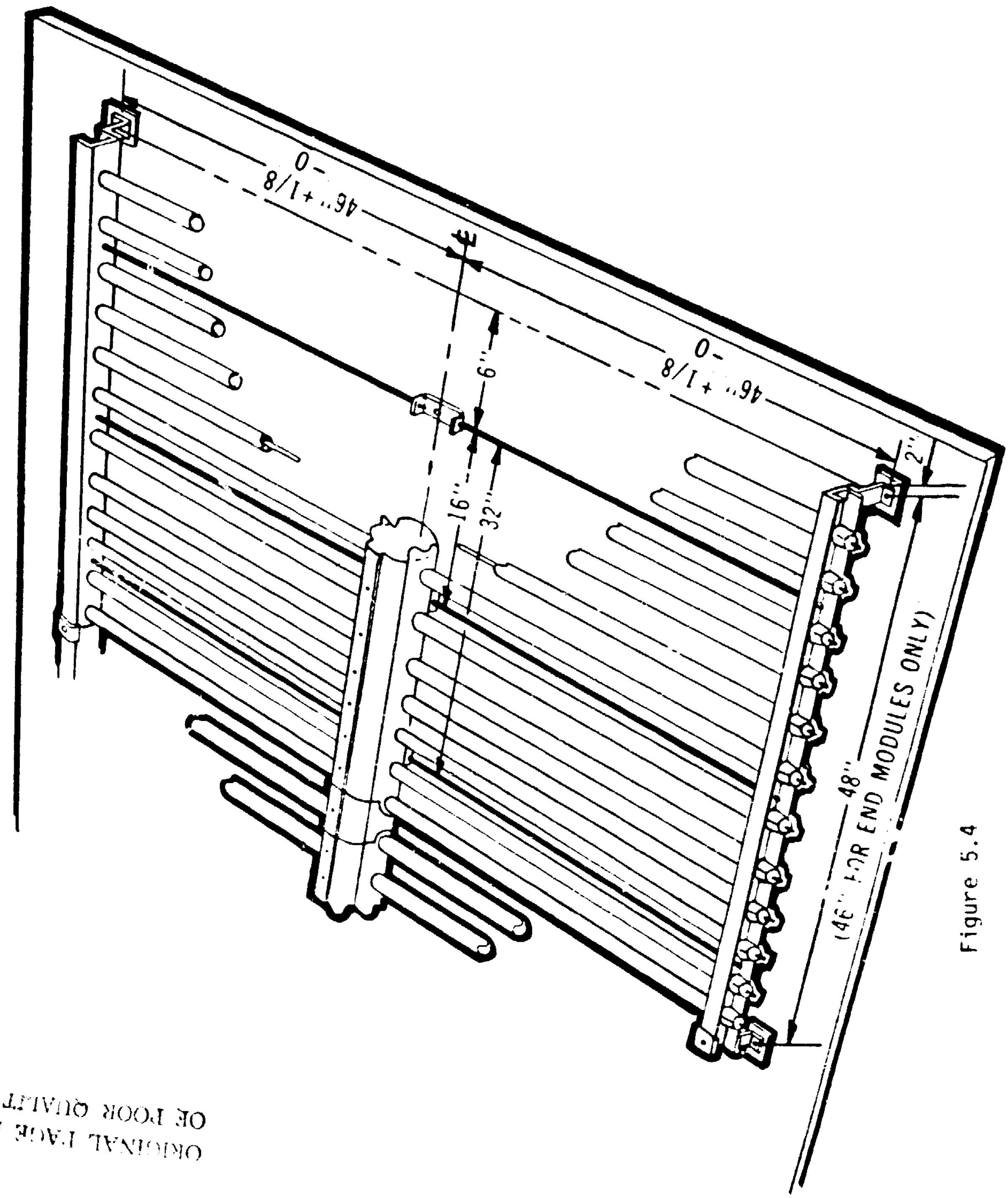


Figure 5.4

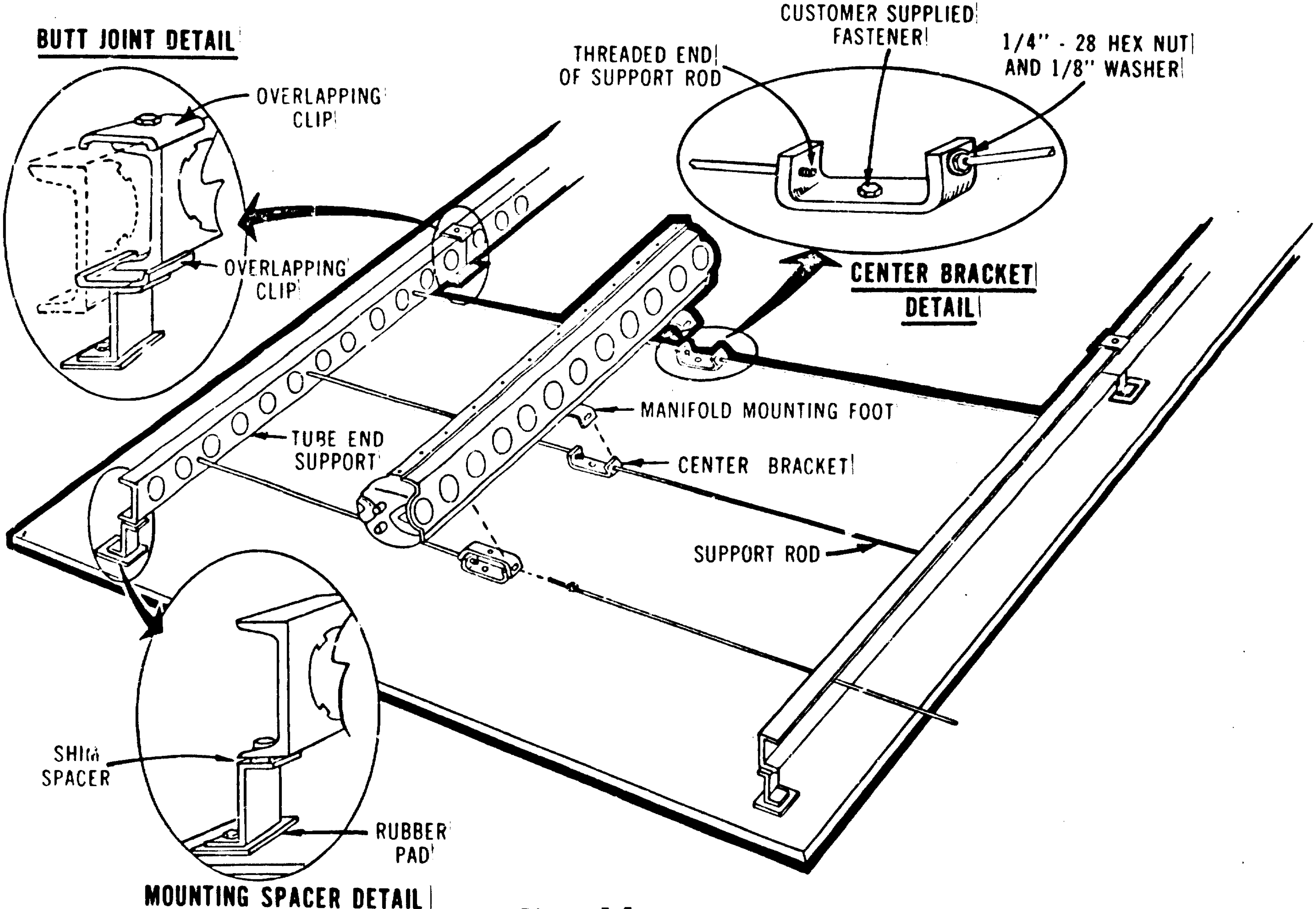

BUTT JOINT DETAIL
OVERLAPPING CLIP
OVERLAPPING CLIP
THREADED END OF SUPPORT ROD
CUSTOMER SUPPLIED FASTENER
1/4" - 28 HEX NUT AND 1/8" WASHER
CENTER BRACKET DETAIL
MANIFOLD MOUNTING FOOT
TUBE END SUPPORT
CENTER BRACKET
SUPPORT ROD
SHIM SPACER
RUBBER PAD
MOUNTING SPACER DETAIL

Figure 5.5

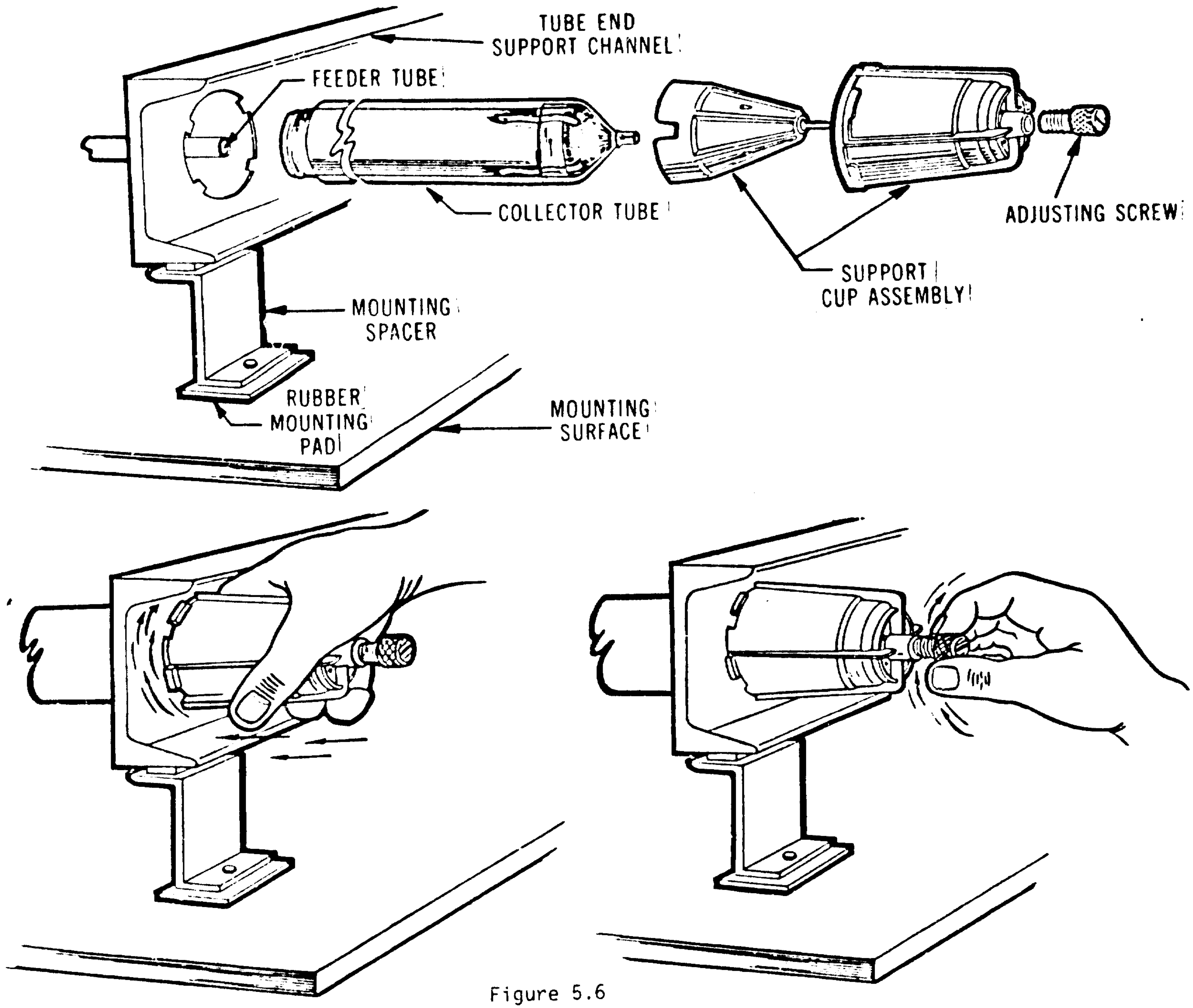
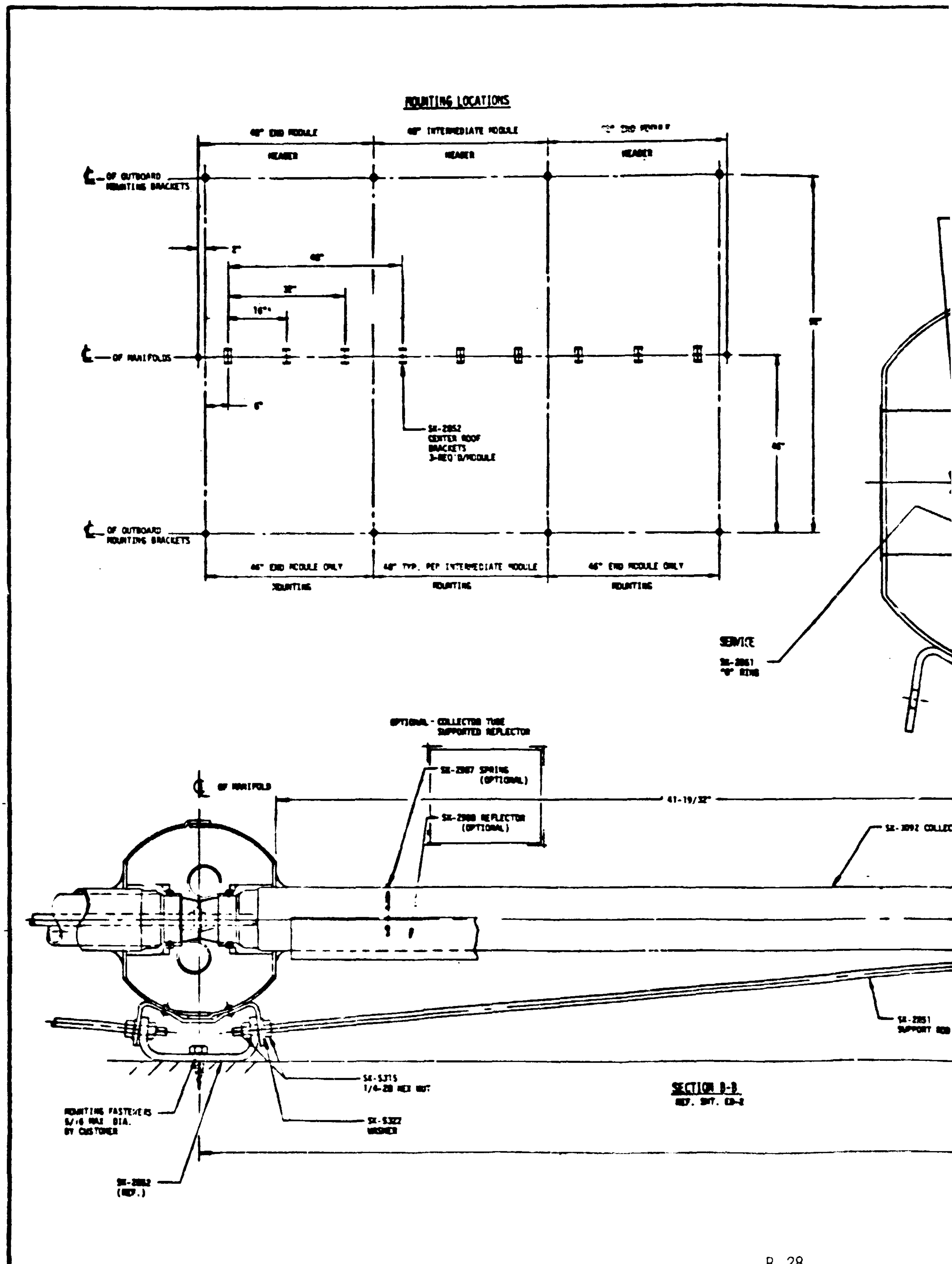
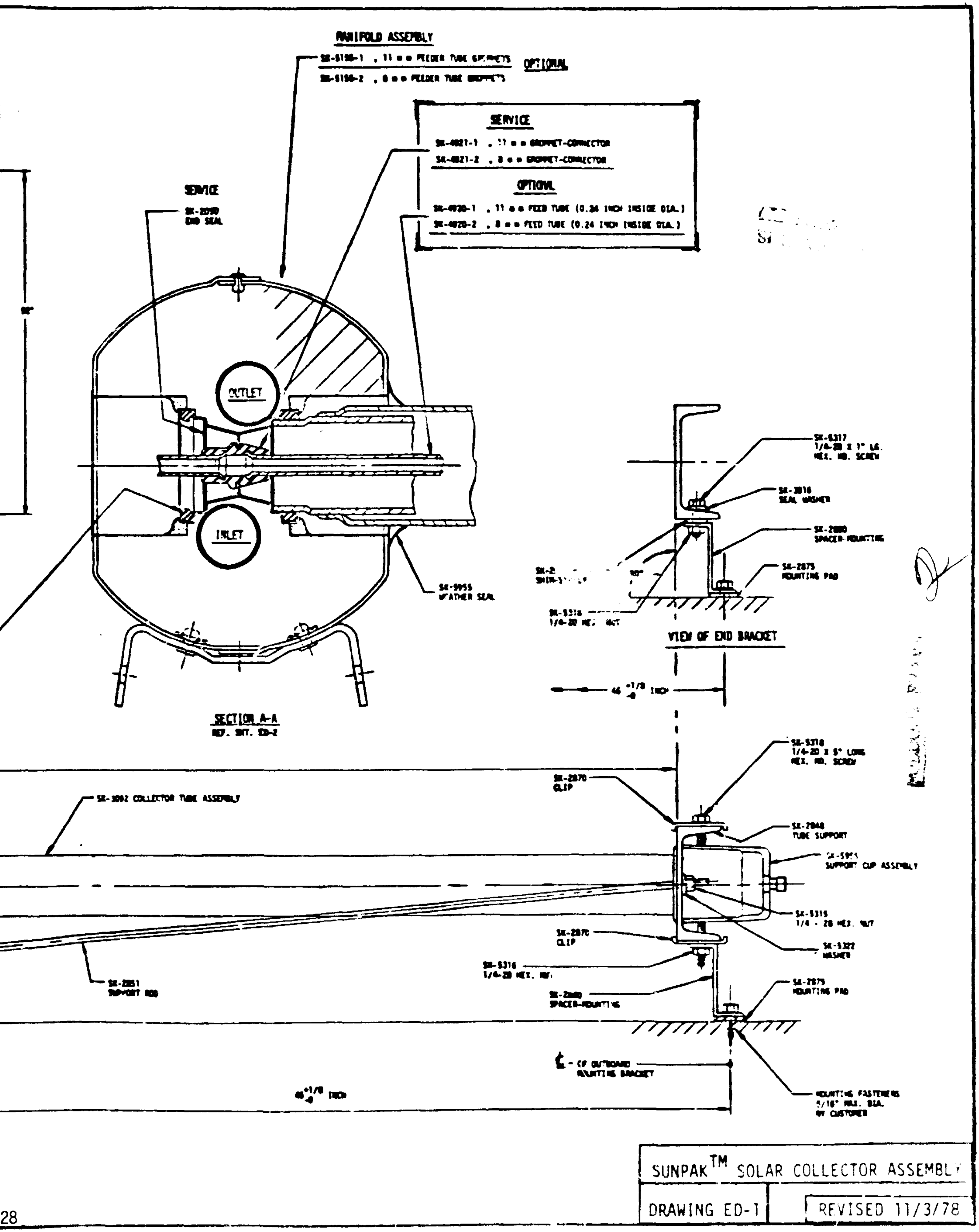
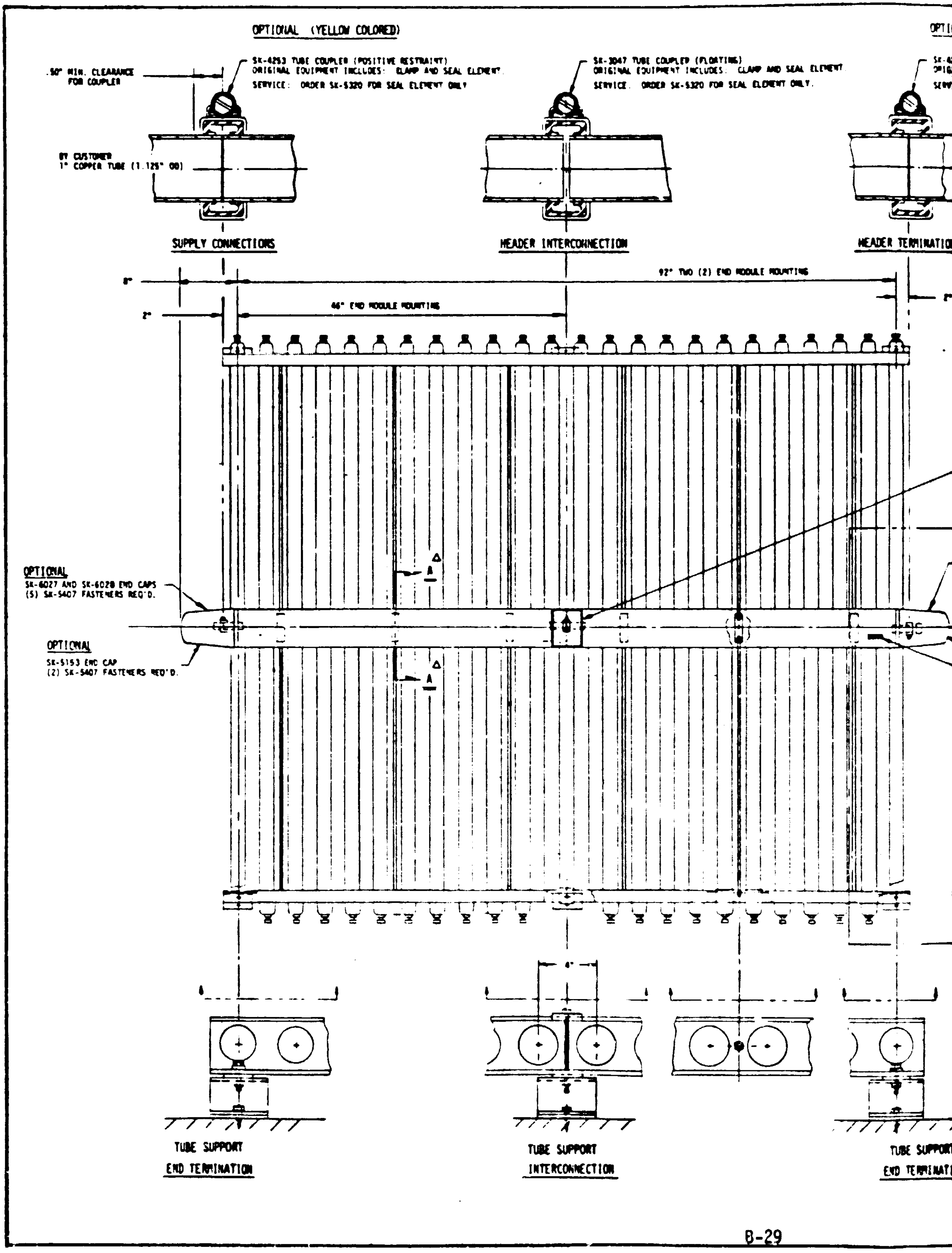

TUBE END
SUPPORT CHANNEL
FEEDER TUBE
COLLECTOR TUBE
ADJUSTING SCREW
SUPPORT
CUP ASSEMBLY
MOUNTING
SPACER
RUBBER
MOUNTING
PAD
MOUNTING
SURFACE

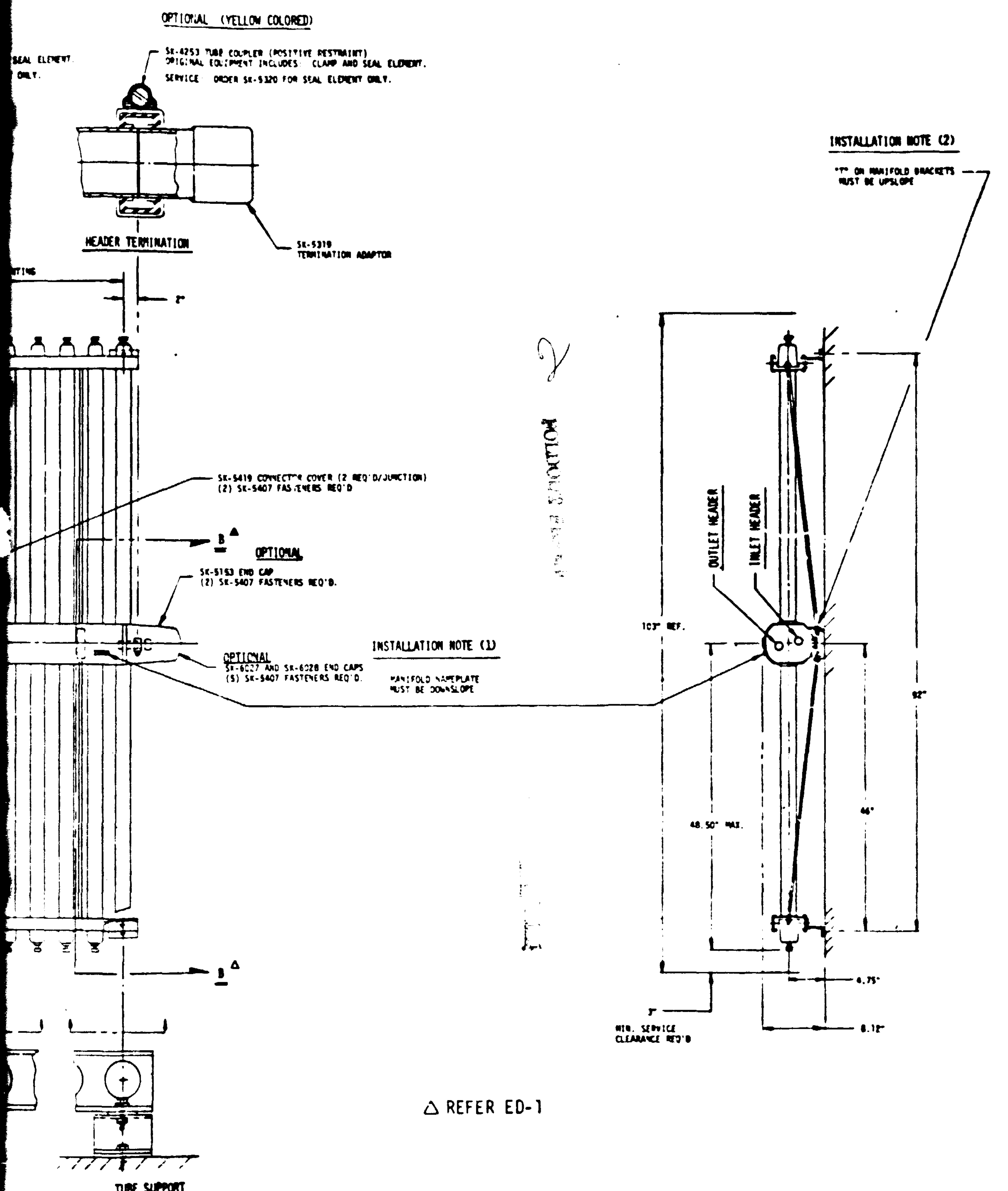
Figure 5.6


MOUNTING LOCATIONS
48" END MODULE
48" INTERMEDIATE MODULE
HEADER
OF OUTBOARD MOUNTING BRACKETS
2"
48"
32"
16"
OF MANIFOLDS
6"
SK-2852 CENTER ROOF BRACKETS 3-REQ'D/MODULE
46"
OF OUTBOARD MOUNTING BRACKETS
46" END MODULE ONLY
48" TYP. PER INTERMEDIATE MODULE
MOUNTING
SERVICE
SK-2861 "O" RING
OPTIONAL - COLLECTOR TUBE SUPPORTED REFLECTOR
SK-2907 SPRING (OPTIONAL)
OF MANIFOLD
41-19/32"
SK-2908 REFLECTOR (OPTIONAL)
SK-5315 1/4-20 HEX NUT
SK-5322 WASHER
SK-2851 SUPPORT ROD
SECTION B-B
MOUNTING FASTENERS BY CUSTOMER


MANIFOLD ASSEMBLY
OPTIONAL
SERVICE
OPTIONAL
SERVICE
OUTLET
INLET
SK-9955 WEATHER SEAL
SECTION A-A
VIEW OF END BRACKET
SK-2880 SPACER-MOUNTING
SK-2875 MOUNTING PAD
SK-3092 COLLECTOR TUBE ASSEMBLY
SK-2851 SUPPORT ROD
SK-2870 CLIP
SK-2848 TUBE SUPPORT
SK-5322 WASHER
MOUNTING FASTENERS 5/16" MAX. DIA. BY CUSTOMER
SUNPAK TM SOLAR COLLECTOR ASSEMBLY
DRAWING ED-1
REVISED 11/3/78

FOLDOUT FRAME





SUNPAK™ SOLAR COLLECTOR TWO (2) MODULE LAYOUT

DRAWING ED-2

REVISED 11/3/78

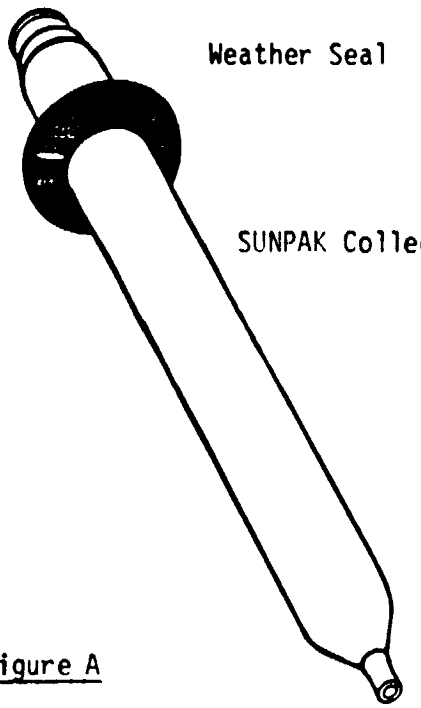


Figure A

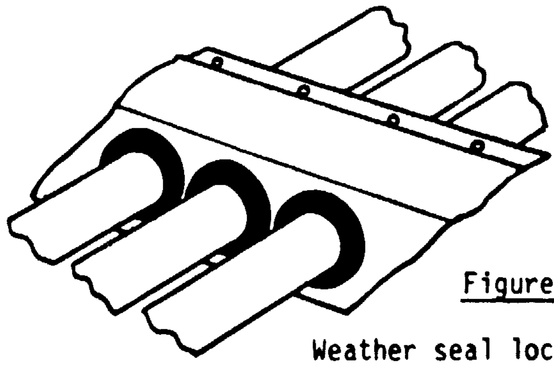


Figure B

Weather seal located against manifold cover.

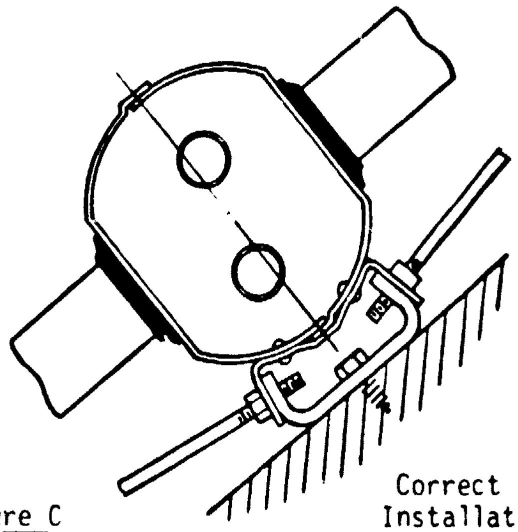


Figure C

Correct Installation

1.0 Description

Figure A illustrates the weather seal (SK-5955) inserted over a SUNPAK™ collector tube. The weather seal is a black rubber gasket 3-1/2" in diameter with an opening of 2" that fits over the collector tube. When installed it reduces the heat loss from the collector tube manifold connection.

1.1 Installation

The installation of the weather seal should be together with the feeder tube (SK-4920) and the collector tube (SK-3092) installation described in Section 2.5 of the SUNPAK™ Solar Collector Installation, Service, and Operating Manual.

The weather seal is placed over the collector tube about 3-6" from the neck end prior to installing the tube into the manifold. After insertion of the collector tube into the manifold and adjustment of the support cup assembly (SK-3048), the weather seal may be located against the manifold cover. The rubber weather seal should be brought into contact with the manifold cover so that it lies snugly on the cover (Figure C). The seal is not to be forced into the manifold opening between the glass and manifold wall. Proper installation of the rubber weather seal will prevent most rain and snow from entering the manifold cup hole.

APPENDIX C

CONTROL SYSTEM DRAWINGS, HONEYWELL

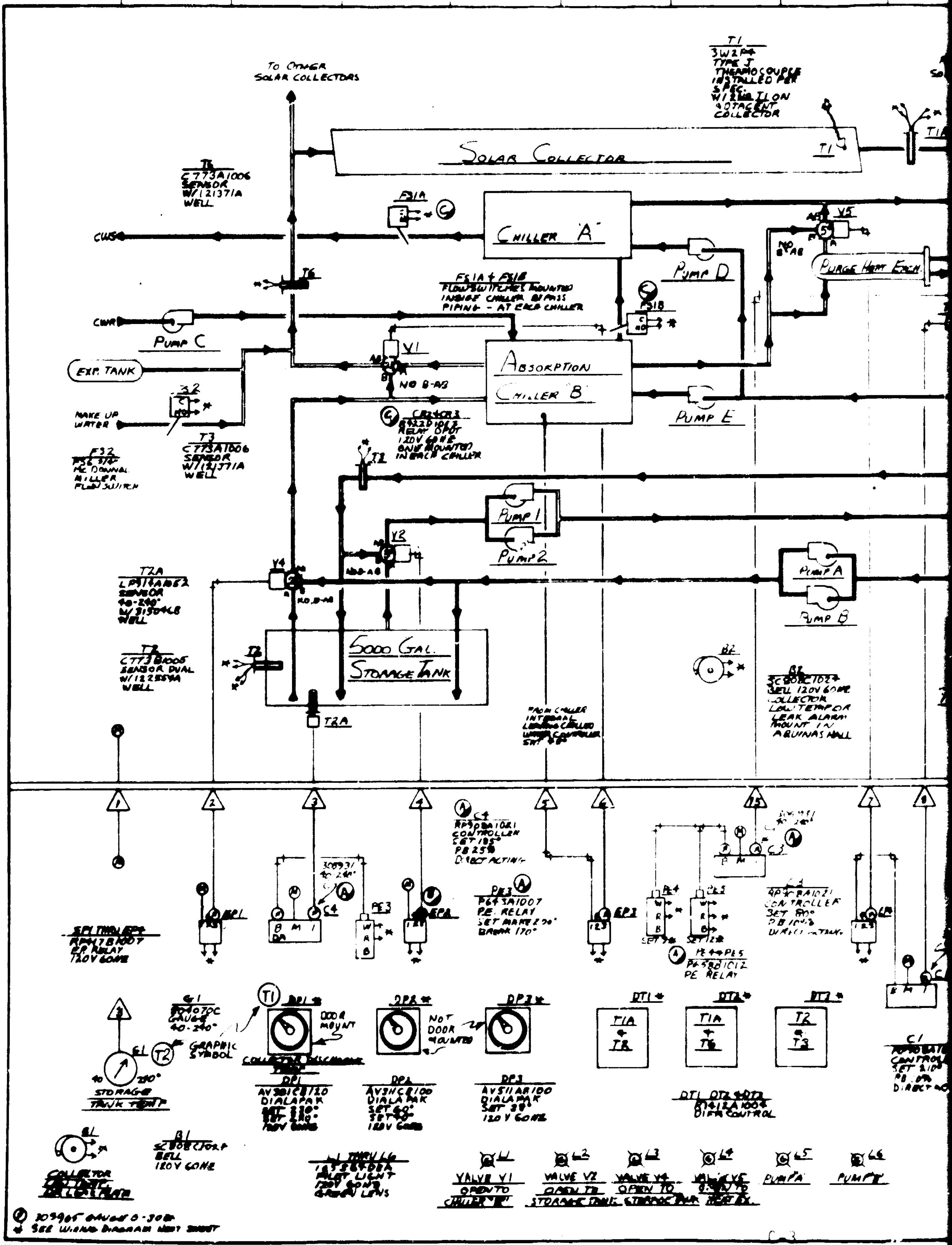
TEMPERATURE CONTROL FOR

COLUMBUS TECHNICAL

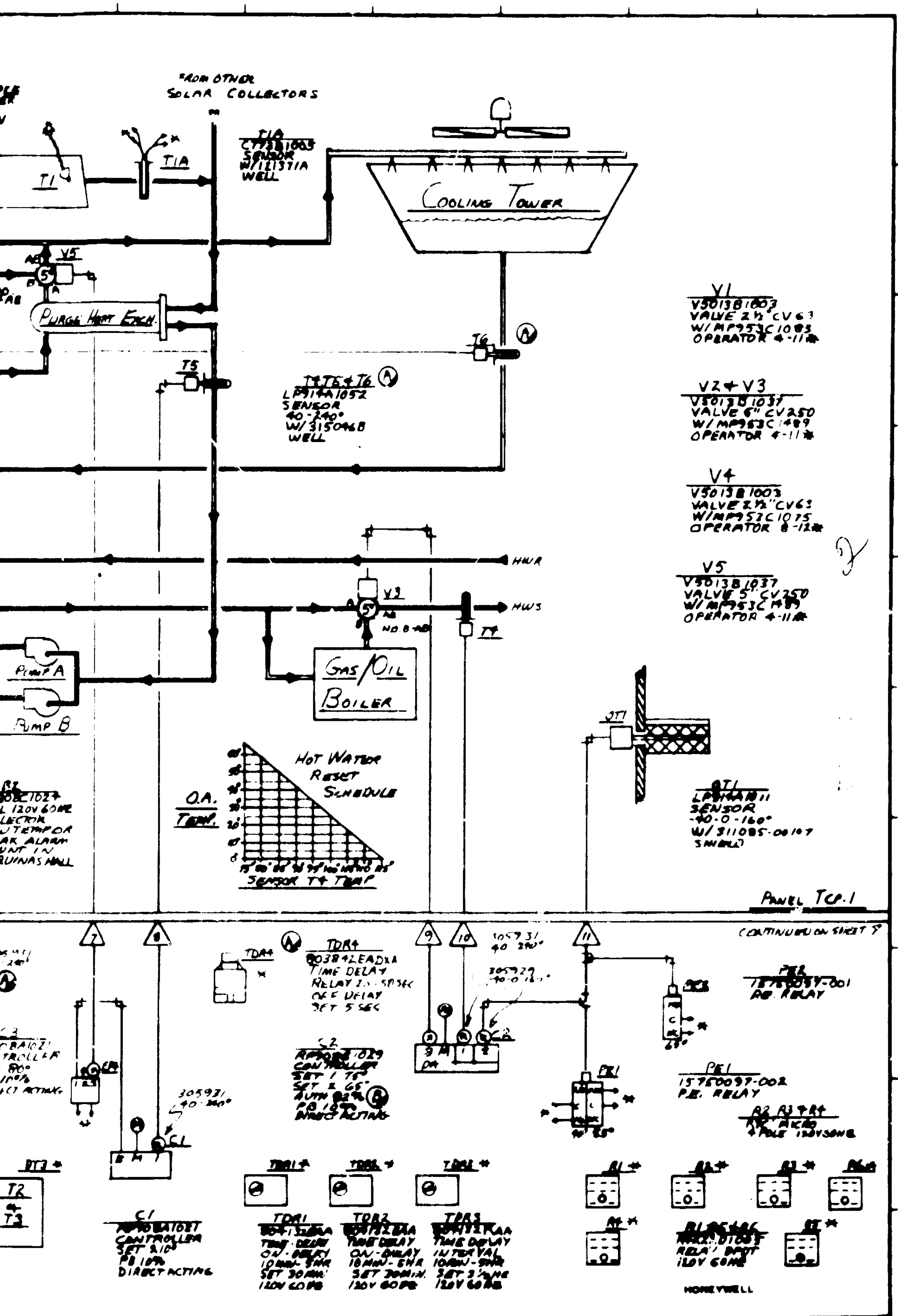
BY

Honeywell

1320 DUBLIN ROAD COLUMBUS OHIO 43215



To Other Solar Collectors
T1
3W2P4
Type J
Thermocouple
Installed Per
Spec
W/Silicon
Adjacent
Collector
Solar Collector
T1A
Chiller 'A'
V5
Purge Heat Exch.
Pump D
CWS
CWR
Pump C
Exp. Tank
Absorption
Chiller 'B'
Pump E
V1
Make Up Water
T3
C773A1006
Sensor
W/121371A
Well
Pump 1
Pump 2
V2
V4
T2A
Pump A
Pump B
5000 Gal. Storage Tank
B2
Aquinas Hall
SP1 Thru EP8
RP417B1007
EP Relay
120V Coils
C4
PE3
P643A1007
PE Relay
PE4 + PE5
PE Relay
C3
DP1
DP2
DP3
Door Mount
Not Door Mounted
Graphic Symbol
G1
40-240°
Storage Tank Temp
DT1
DT2
DT3
T1A
T2
T6
T3
DT1, DT2 + DT3
Diff. Control
C1
B1
Bell
120V Coil
L1 Thru L6
Pilot Light
Green Lens
L1
L2
L3
L4
L5
L6
Valve V1 Open to Chiller 'B'
Valve V2 Open to Storage Tank
Valve V4 Open to Storage Tank
Valve V5 Open to Heat Ex.
Pump A
Pump B
See Wiring Diagram Next Sheet



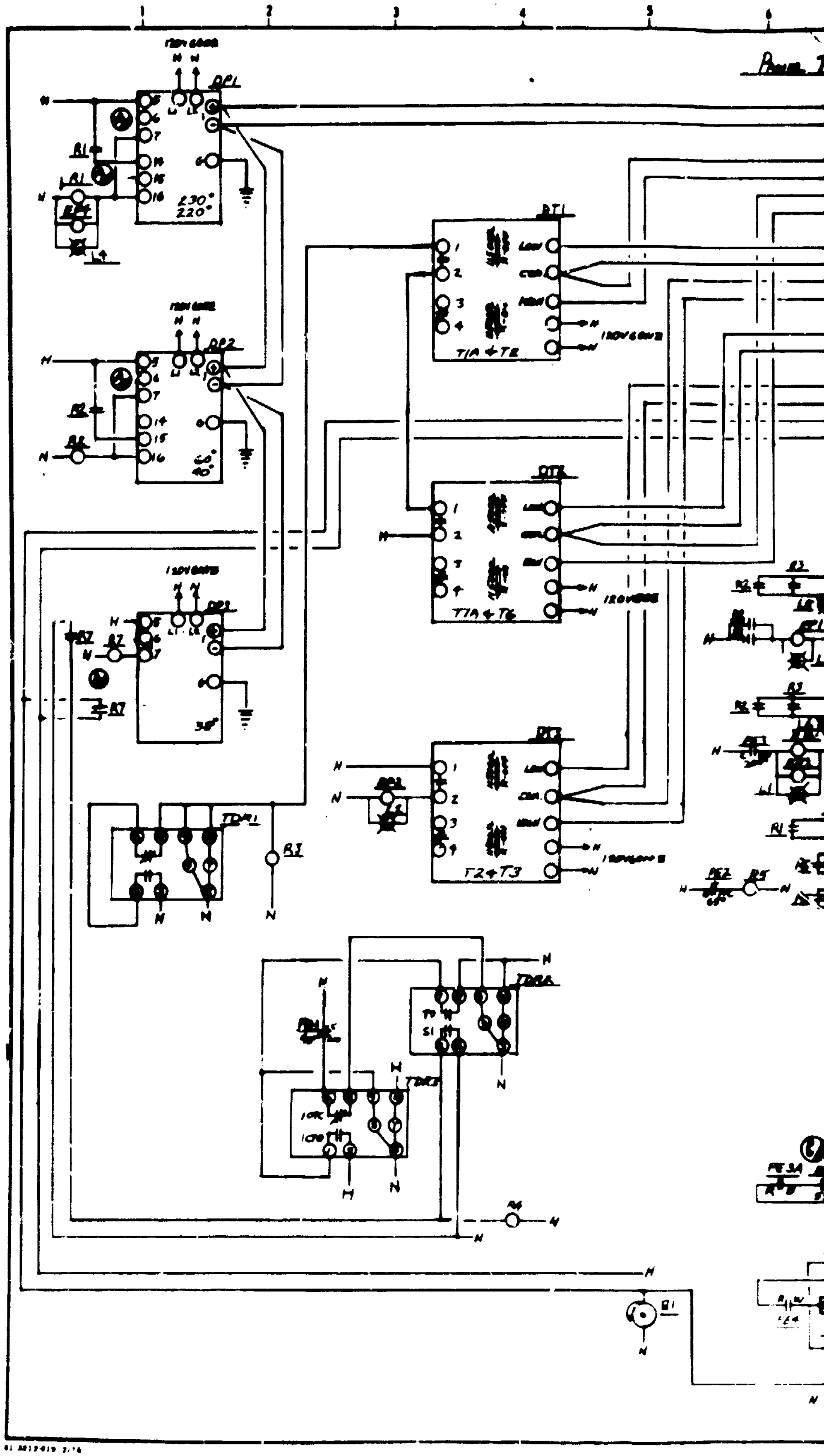
C	PUMP - CHILLER INTERLOCK	5-21-79	RCN
B	AS BUILT	3-13-79	RCN
A	PER SUBMITTAL	9-6-78	RCA
REVISIONS		DATE	APPD

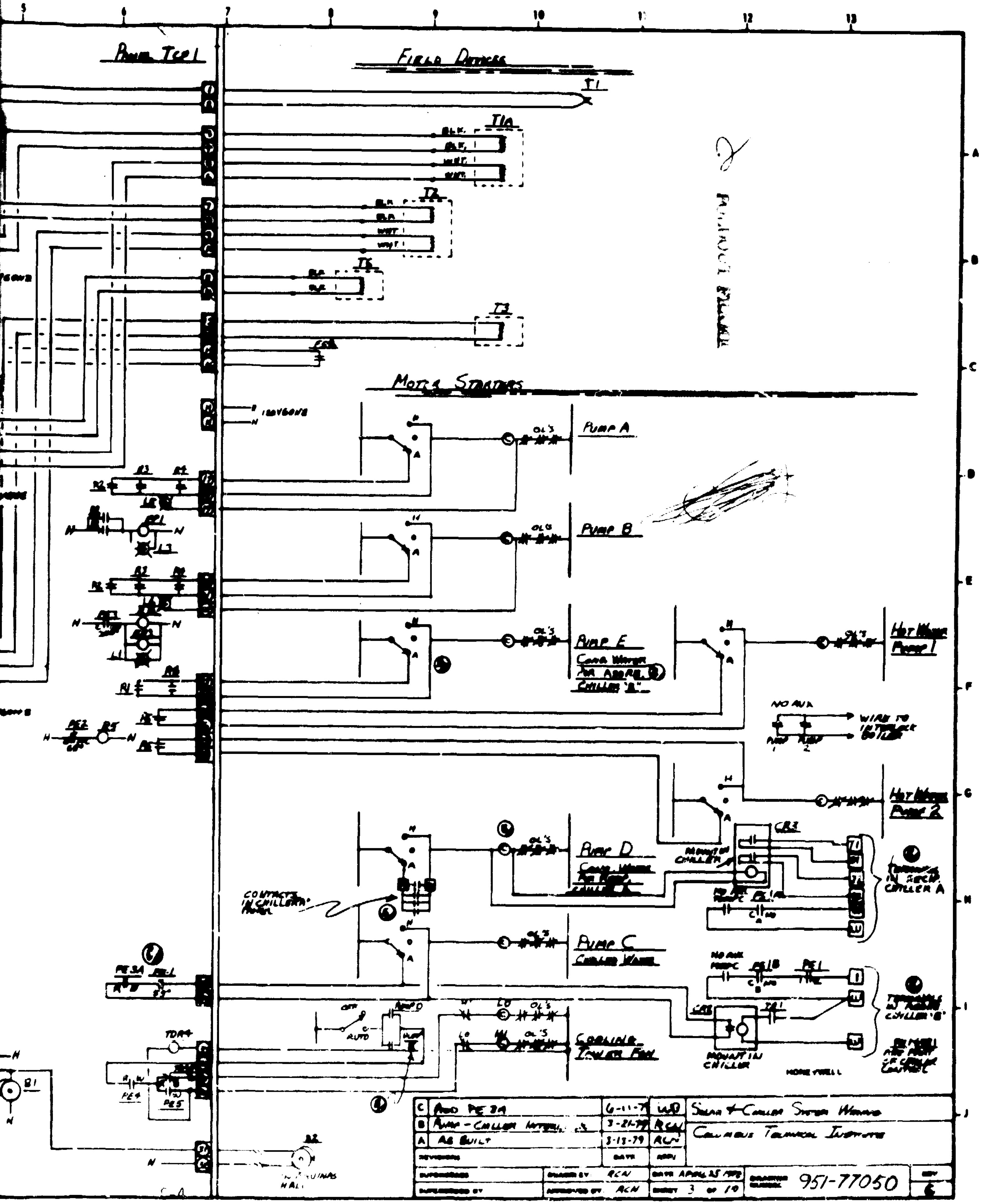
SOLAR ENERGY SYSTEM

COLUMBUS TECHNICAL INSTITUTE

SUPERSEDES	DRAWN BY: RCN	DATE APRIL 21 1978	DRAWING NUMBER 951-77050
SUPERSEDED BY	APPROVED BY: RCN	SHEET 2 OF 10	REV B

FOLDOUT FRAME 1





C	Add PE 3A	6-11-79	WD
B	Pump - Chiller Interlocks	3-21-79	RCN
A	As Built	3-13-79	RCN
Revisions		Date	Appr

Solar + Chiller System Wiring

Columbus Technical Institute

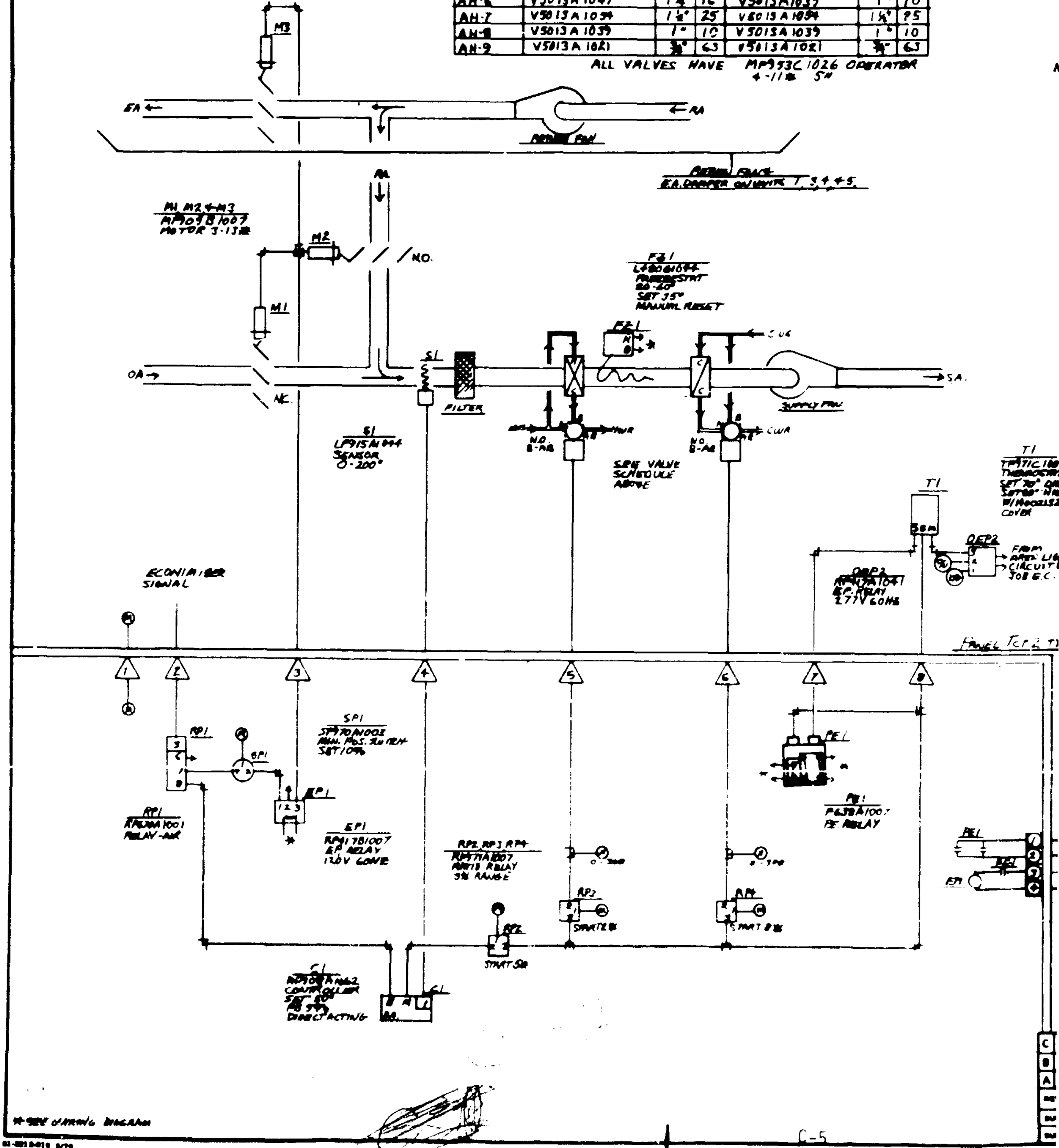
Drawn by: RCN — Date: April 25 1978 — Drawing number: 951-77050

Approved by: RCN — Sheet 3 of 19 — Rev: C

VALVE SCHEDULE

AH UNIT	COOLING VALVE	SIZE	CV	HEATING VALVE	SIZE	CV
AH-1	V5013A1021	3/4"	6.3	V5013A1021	3/4"	6.3
AH-2	V5013A1054	1 1/2"	25	V5013A1039	1"	10
AH-3	V5013A1054	1 1/2"	25	V5013A1047	1 1/4"	16
AH-4	V5013A1054	1 1/2"	25	V5013A1047	1 1/4"	16
AH-5	V5013A1054	1 1/2"	25	V5013A1047	1 1/4"	16
AH-6	V5013A1047	1 1/4"	16	V5013A1039	1"	10
AH-7	V5013A1054	1 1/2"	25	V5013A1054	1 1/2"	25
AH-8	V5013A1039	1"	10	V5013A1039	1"	10
AH-9	V5013A1021	3/4"	6.3	V5013A1021	3/4"	6.3

ALL VALVES HAVE MP953C1026 OPERATOR 4-11# 5#



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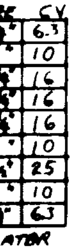


MATERIAL LIST

Qty.	Part No.	Description
22	MP909B1007	Motor
9	LP915A1044	Sensor
9	L480G1044	Freezestat
9	RP417A1041	E.P. Relay
9	TP971C1009	Thermostat
9	14002132-201	Cover
9	15753253-003	Ring

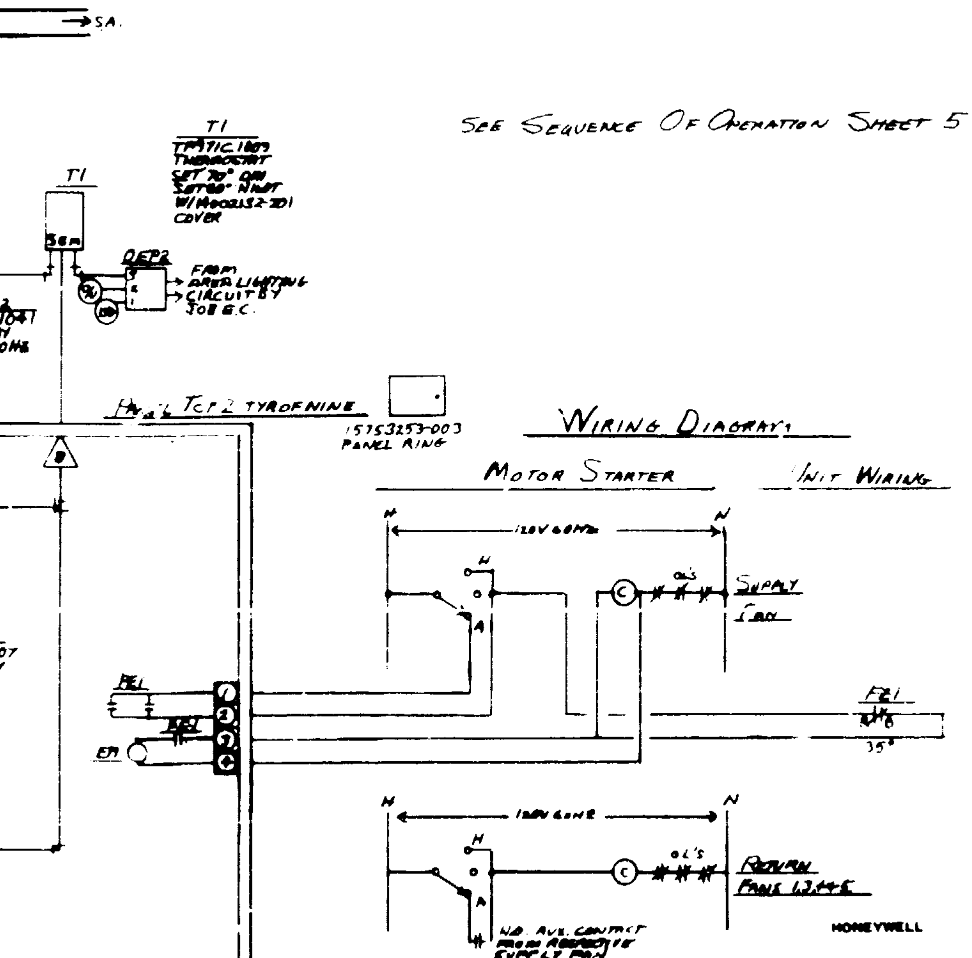
Assembled Valves consisting of:

4	V5013A1021	Valve
4	MP953C1026	Operator
4	V5013A1039	Valve
4	MP953C1026	Operator
6	V5013A1054	Valve
6	MP953C1026	Operator

9 Special Panels consisting of:

1	RP908A1062	Controller
3	RP971A1007	Relay
1	RP670A1001	Relay
1	SP970A1003	Min. Switch
1	RP417B1007	E.P. Relay
1	P658A1007	P.E. Relay

SEE SEQUENCE OF OPERATION SHEET 5



C				AN1 THRU AN9 CONTROL
B				COLUMBUS TECHNICAL INSTITUTE
A				
REVISIONS		DATE	APPD.	
SUPERSEDES	DRAWN BY: RCN	DATE NOV 19, 1987	DRAWING NUMBER 951-77050	REV.
SUPERSEDED BY	APPROVED BY: RCN	SHEET 4 OF 10		

SEQUENCE OF OPERATION

Solar Energy Control System

When the solar collector discharge temperature is higher than the storage tank, solar hot w
pumps "A" & "B" run for a minimum of ½ hour and continue to run as long as the collector is
than the tank. Pumps "A" and "B" also run continuously if sensor T1 in the collector disch
fails. If the outside air temperature drops below 40°, pumps "A" and "B" cycle on for ½ ho
every four hours. Anytime the collector discharge temperature drops to 40°, pumps "A" and
run until the discharge reaches 60°. When pumps "A" and "B" run, valve V4 positions for fl
to the storage tank.

If the collector discharge temperature exceeds 230°, pump "E" and the cooling tower fans ru
and valve V5 is put under control of sensor T5 to maintain 210° until the collector dischar
temperature drops to 220°. When pump "E" is off, valve V5 bypasses the purge converter.

If the collector discharge temperature drops below 38°, or sensor T1 fails or the leak detector senses flow in the make-up line, a bell in the panel and a remote bell in Aquinas Hall rings until the condition is corrected.

Boiler Operation When outside air temperature is below 65°, hot water pumps 1 & 2 run. Valve V2 positions to bypass the storage tank anytime sensor T3 is warmer than the storage tank. Valve V3 is positioned according to the reset schedule shown.

Chilled Water System During the occupied cycle when the outside temperature is above 55° pump "C" runs. When the storage tank water temperature exceeds 200°, the absorption machine and condenser pump "E" and the cooling tower fan runs and valve V1 is allowed to modulate under control of the internal controller of the absorption machine until the tank drops below 170°.

AH1- thru 9 (Sheet 4)

The supply fan runs continuously during the "occupied" mode and cycles to maintain the lower night setting of the thermostat in the "unoccupied" mode. When the specified lighting circuit for the unit is energized, the unit is automatically put in the "occupied" operation.

The space thermostat modulates the mixing dampers, the heating coil valve, and the cooling coil valve in sequence to maintain its setting. The mixing dampers can be overridden by the mixed air low limit. The Central Economizer signal closes the outside damper to minimum position when the outside temperature exceeds 68°.

If the freezestat senses heating coil discharge temperature of 35° or less, the fan stops and the outside damper closes. The freezestat must be manually reset.

Sequence of Operation - Heat Wheel - PhotoLab Area (Sheet 6)

The photo area unit supply & exhaust fans run during the "occupied" cycle to supply the duct coils.

The space thermostats modulate the heating coil & cooling coil valves in sequence to maintain their setting. The thermostat with the greatest demand for cooling is allowed to control the speed of the heat wheel when the outside air is cooler than the return air temperature. When the outside temperature is above that of the return air, the heat wheel runs at maximum speed. When the wheel is at min. speed & excess heat transfer remains, the wheel stops. (A)
During "unoccupied" cycle the fans are off and the outside damper closes. If the space temperature falls below the setpoint of the night thermostat, the fans run with the outside damper closed and the bypass damper open. If the designated lighting circuit is energized, the system is put in "occupied" operation.

Cooling Tower Control

(A) The tower fan is interlocked with the condensor water pumps, and runs in low speed when the condensor water temperature rises above 75° and goes to high speed any time the condensor water temperature reaches 80°.

ARCHITECT:
ENGINEER:
CONTRACTOR:

5 6 7 8 9 10 11 12 13

rage tank, solar hot water
ng as the collec... is hotter
in the collector discharge
"B" cycle on for ½ hour,
to 40°, pumps "A" and "B"
ve V4 positions for flow

cooling tower fans run
the collector discharge
he purge converter.

fails or the leak
emote bell in

r pumps 1 & 2 run.
rmer than the storage

erature is above 55°
the absorption
ve V1 is allowed to
achine until the tank

s to maintain
When the
tomatically put in

alve, and the
ampers can
nal closes
xceeds 68°.

less, the fan
reset.

ycle to supply

in sequence to
cooling is allowed
than the return
eturn air, the
cess heat transfer

ses. If the space
s run with the
lighting circuit

in low speed when
ed any time the

CT1 **MATERIAL LIST**

Qty.	Part Number	Description
2	C773B1005	Sensor
2	C773A1006	Sensor
3	121371A	Well
1	122554A	Well
3	LP914A1052	Sensor
3	315046B	Well
1	LP914A1011	Sensor
1	311685-00107	Shield
1	SC808C1024	Bell
1	MAMFS74D	Flow Switch
1	MAMFS6 3/4"	Flow Switch
2	3W2P4	Thermocouple

Panel TCP-1 consisting of:

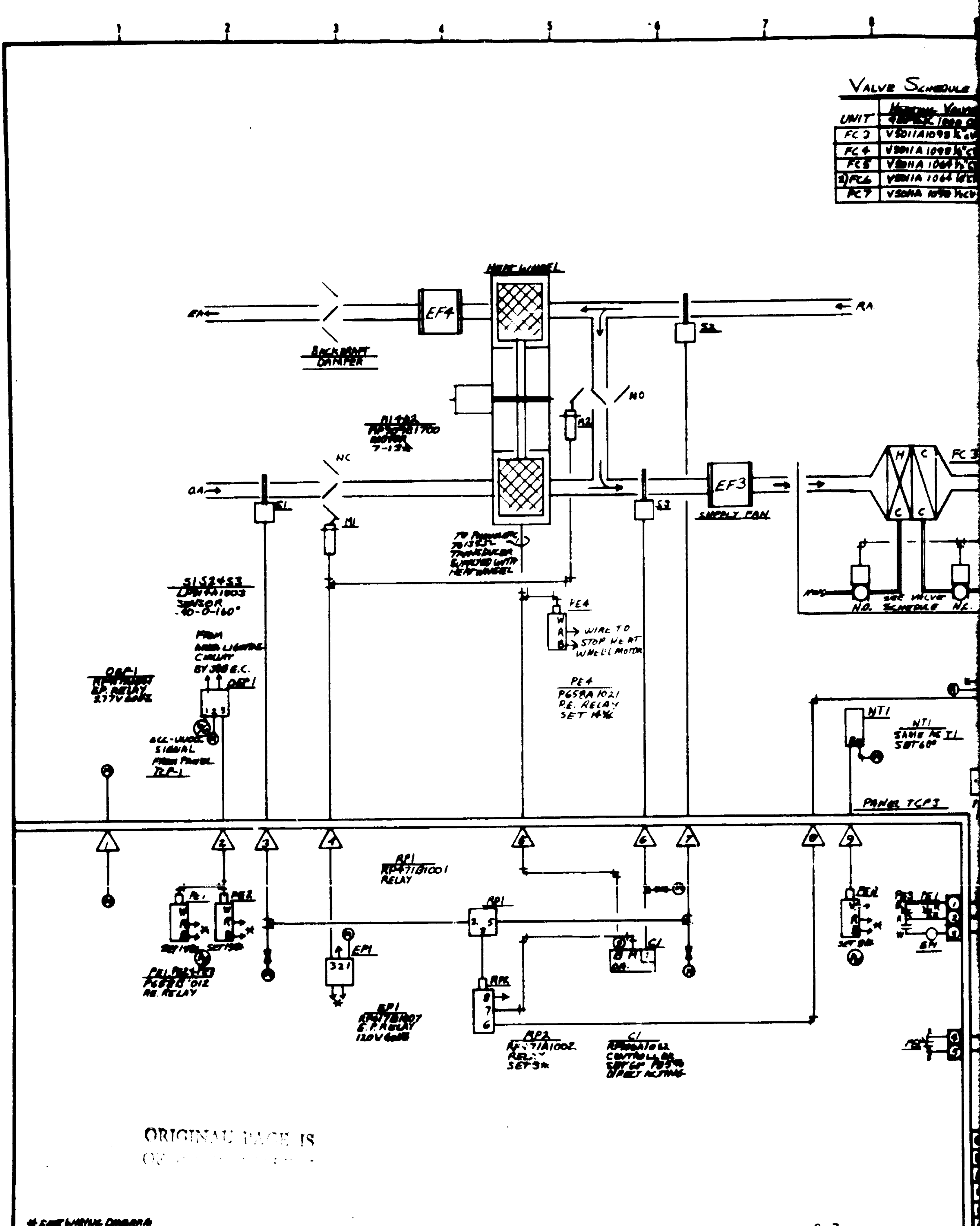
Qty.	Part Number	Description
5	RP417B1007	E.P. Relay
2	15750097-001	P.E. Relay
1	15750097-002	P.E. Relay
2	RP908A1021	Controller
1	RP908B1029	Controller
2	804132EAA	Time Delay
1	804132KAA	Time Delay
3	R4222D1005	Relay
3	RYC MICRO	Relay
3	R7412A1004	Diff. Control
1	AV301CB120	Dial-A-PAC
1	AV311CB100	Dial-A-PAC
1	AV511AB100	Dial-A-PAC
6	165364DBA	Pilot Light
1	SC808C1024	Bell
1	804070C	Gauge
5	305965	"
2	305931	"
1	305929	"
1	S659B1049	Time Clock
1	11TS115-1	Switch
1	VP519C1006	Valve
1	RP471A1002	Air Relay
1	NRNR04200RGE	PRV

Assembled Valves consisting of:

Qty.	Part Number	Description
1	V5013B1003	Valve
1	MP953C1083	Operator
2	V5013B1037	Valve
2	MP953C1489	Operator
1	V5013B1003	Valve
1	MP953C1075	Operator
1	V5013B1037	Valve
1	MP953C1489	Operator

HONEYWELL

C				MATERIAL & SEQUENCE FOR SOLAR CONTROL
B				COLUMBUS TECHNICAL INSTITUTE
A	PER SUBMITTAL	9-8-78	RCN	
REVISIONS		DATE	APPD.	
SUPERSEDES	DRAWN BY: RCN	DATE APRIL 26 1978	DRAWING NUMBER 951-77050	REV. A
SUPERSEDED BY	APPROVED BY: RCN	SHEET 5 of 10		



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FOLDOUT FRAME

Valve Schedule For FC3 – FC7

Unit	Heating Valve [illegible] 1000 Opr.	Cooling Valve [illegible] 1107 Opr.
FC3	V5011A1098 1/2" CV4	V5011A1155 [illegible]
FC4	V5011A1098 1/2" CV4	V5011A[illegible] 1/2" CV4
FC5	V5011A1064 1/2" CV[illegible]	V5011A1064 1/2" CV[illegible]
(2) FC6	V5011A1064 1/2" CV2.5	V5011A1064 1/2" CV2.5
FC7	V5011A1098 1/2" CV4	V5011A1098 1/2" CV4

MATERIAL LIST

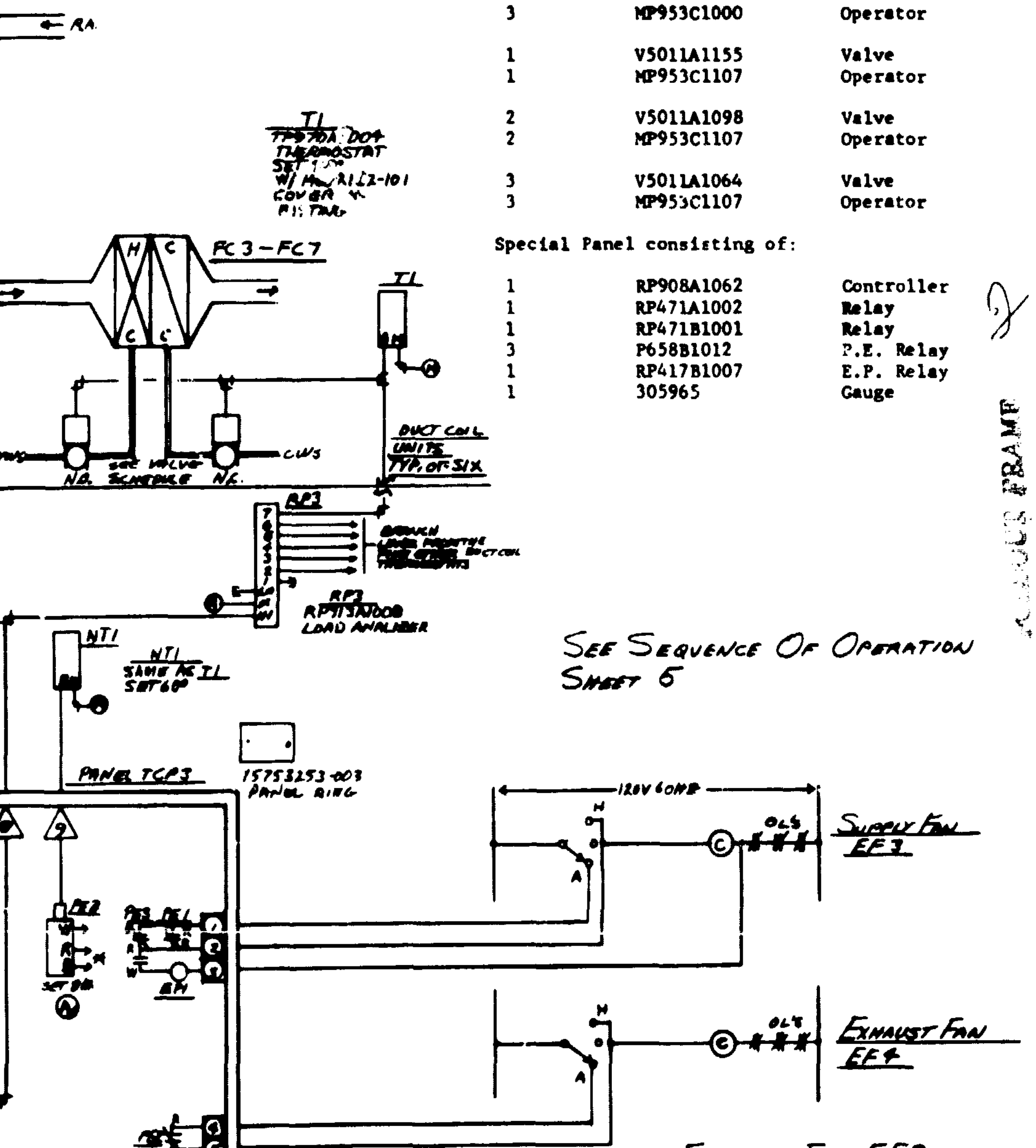
Qty.	Part No.	Description
3	LP914A1003	Sensor
2	MP909B1700	Motor
1	RP913A1008	Load Analyzer
1	RP417A1041	E.P. Relay
7	TP970A1004	Thermostat
7	14002132-101	Cover

Assembled valves consisting of:

Qty.	Part No.	Description
3	V5011A1098	Valve
3	MP953C1000	Operator
3	V5011A1064	Valve
3	MP953C1000	Operator
1	V5011A1155	Valve
1	MP953C1107	Operator
2	V5011A1098	Valve
2	MP953C1107	Operator
3	V5011A1064	Valve
3	MP953C1107	Operator

Special Panel consisting of:

Qty.	Part No.	Description
1	RP908A1062	Controller
1	RP471A1002	Relay
1	RP471B1001	Relay
3	P658B1012	P.E. Relay
1	RP417B1007	E.P. Relay
1	305965	Gauge



See Sequence Of Operation Sheet 6

Exhaust Fan EF8 Runs Continuously

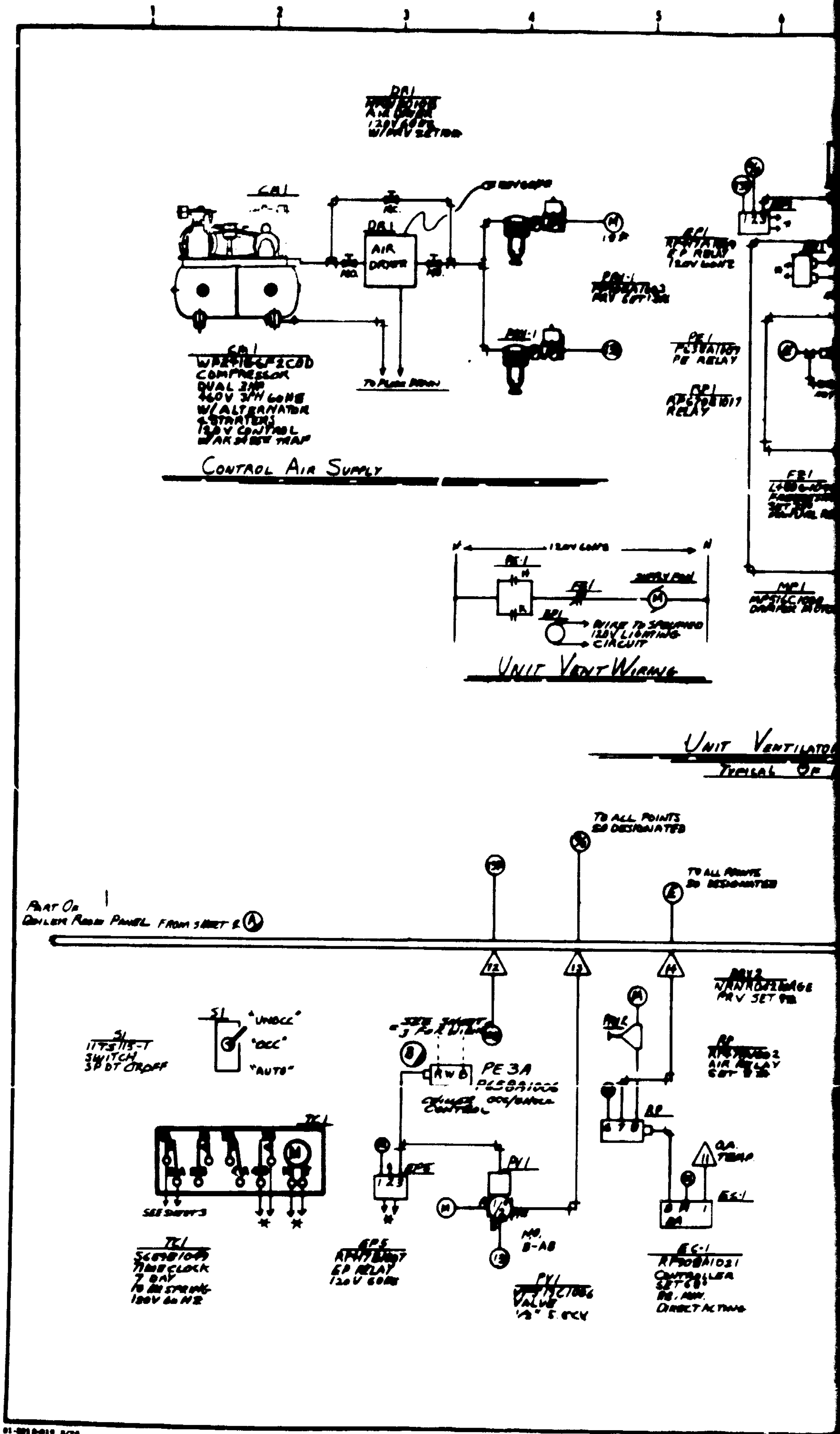
HONEYWELL

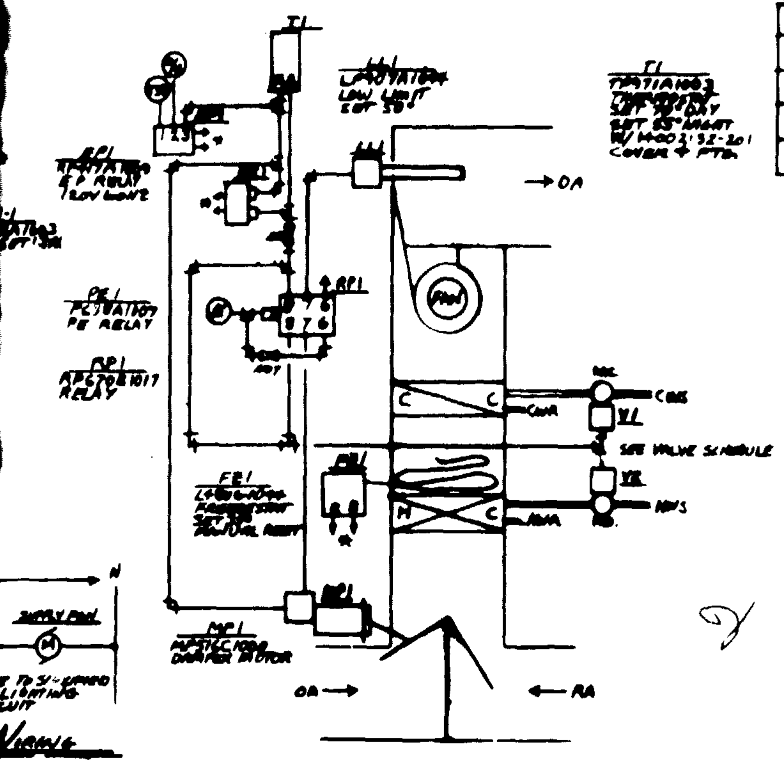
C			
B			
A	As Built	3-1979	RCN
REVISIONS		DATE	APPD.

Heat Wheel - PhotoLab Area

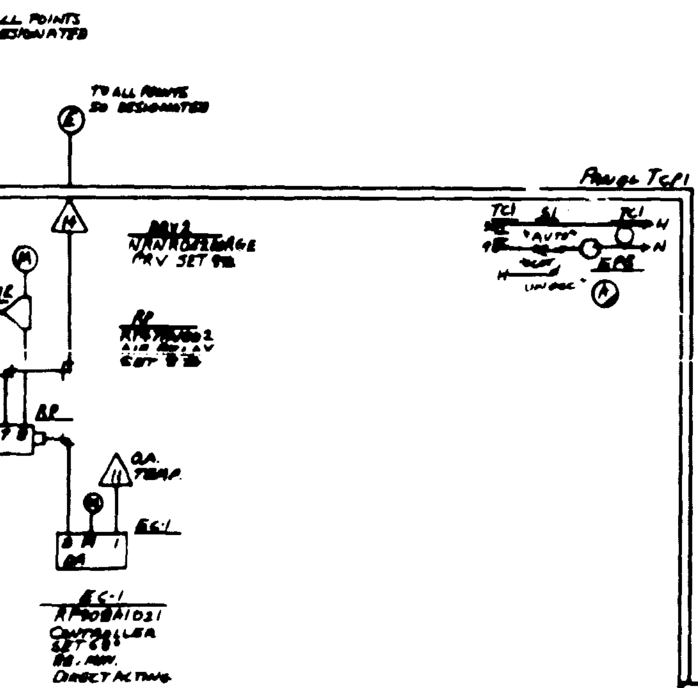
Columbus Technical Institute

SUPERSEDES	DRAWN BY: RCN	DATE Nov 30 1977	DRAWING NUMBER 951-77050
SUPERSEDED BY	APPROVED BY: RCN	SHEET 6 OF 10	REV. A


DR1
AIR DRYER
COMPRESSOR
DUAL 3HP
460V 3PH 60HZ
W/ALTERNATOR
& STARTERS
120V CONTROL
To Floor Drain
Control Air Supply
120V 60HZ
SUPPLY FAN
WIRE TO SPECIFIED
120V LIGHTING
CIRCUIT
Unit Vent Wiring
Unit Ventilator
TO ALL POINTS
SO DESIGNATED
Part Of
Boiler Room Panel From sheet 2
S1
SWITCH
SPDT CR OFF
"UNOCC"
"OCC"
"AUTO"
SEE SHEET 3
PE 3A
TIME CLOCK
7 DAY
120V 60HZ
EP RELAY
120V 60HZ
VALVE
O.A. TEMP
EC-1
CONTROLLER
DIRECT ACTING



Unit Ventilator Control
Typical Of Rowtren



Unit Vent Valve Schedule

Unit	Qty.	Heating Valve	Size	CV	Cooling Valve	Size	CV
UV 1	1	VP512A1213	1/2"	1	VP513B1053	1/2"	2.5
UV 2	4	VP512A1684	3/4"	6.3	V5011A1098 W/MP953D1107	1/2"	4
UV 3	1	VP512A1270	3/4"	4	V5011A1155 W/MP953D1107	3/4"	6.3
UV4	6	VP512A1684	3/4"	6.3			
UV5	2	VP512A1726	1"	10			

SEQUENCE OF OPERATION

Unit Ventilator Control During the "occupied" cycle, the fan runs continuously and the space thermostat operates at its "day" setting. The outside and return dampers, the heating coil valve and the cooling coil valve are modulated in sequence to maintain the thermostat setting.

When the outside air temperature is above 68°, the outside damper closes to minimum position. In the "unoccupied" mode, the fan is normally off but can be cycled on with the outside damper closed and the heating coil valve open anytime the space temperature drops to the "night" setting of thermostat.

The unit will operate in "occupied" mode anytime the respective lighting circuit is energized.

Occupied - Unoccupied Control The time clock is programmed to cycle the air handling units, the unit ventilators and the photoLab system from "occupied" to "unoccupied" mode when switch S1 is in the "auto" position. S1 can be manually positioned to put all the units continuously in "occupied" or "unoccupied" operation.

MATERIAL LIST

Qty.	Part No.	Description
1	MP241G6F2COD	Compressor
1	AK3485 E	Trap
1	HKN8010B	Dryer
1	P902A1003	P.R.V.
14	RP417A1009	E.P. Relay
14	P638A1007	P.E. Relay
14	RP670B1017	Relay
14	LP907A1044	Low Limit
14	L480G1044	Freezestat
14	MP516C1000	Damper Motor
14	TP971A1003	Thermostat
14	14002132-201	Cover
1	VP512A1213	Valve
10	VP512A1684	"
1	VP512A1270	"
2	VP512A1726	"
1	VP513B1053	"

Assembled Valves consist ng of:

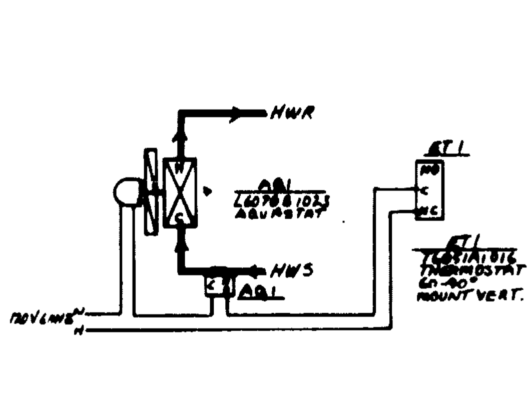
Qty.	Part No.	Description
4	V5011A1098	Valve
4	MP953D1107	Operator
10	V5011A1155	Valve
10	MP953D1107	Operator

HONEYWELL

Rev.	Revisions	Date	Appr.
C			
B	Add PE3A	6-11-77	
A	Change Wiring	6/20/78	RCN

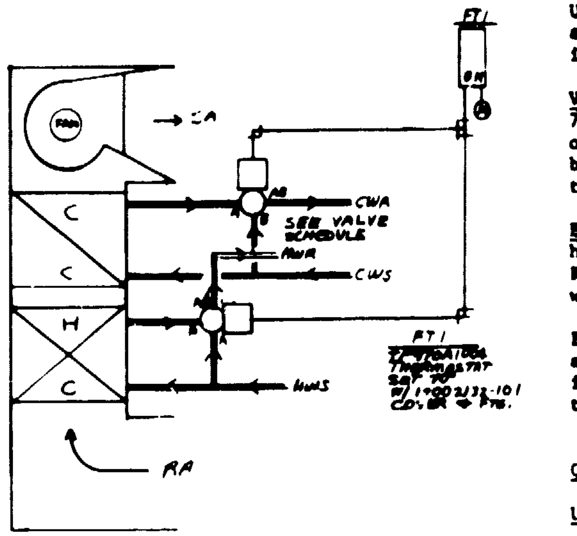
Occ.-Unocc. + Economizer Control
Columbus Technical Institute

Drawn by: RCN Date: Nov. 24, 1977
Approved by: RCN Sheet 7 of 10
Drawing Number: 951-77050



UNIT HEATER CONTROL - 12 TOTAL

TYPICAL FOR CABINET & PROPELLER TYPE

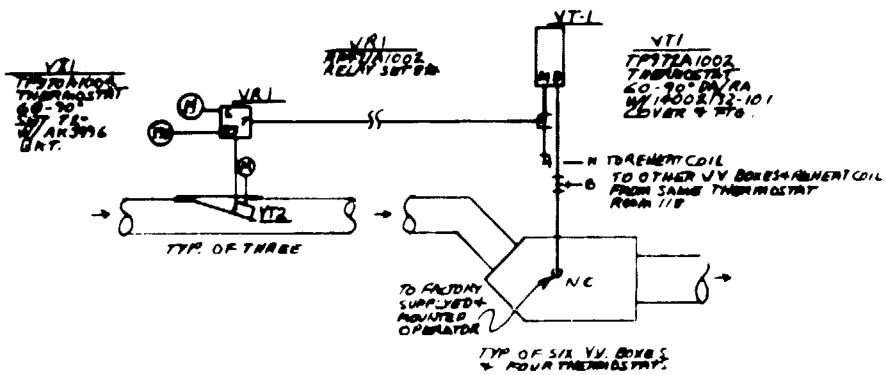


FAN COIL VALVE SCHEDULE

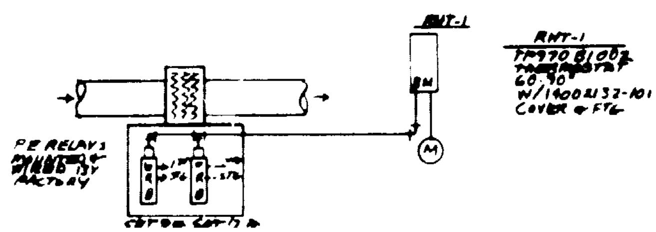
UNIT	QTY	HEATING VALVE	SIZE	CV.	COOLING VALVE	SIZE	CV
FC1	1	V5013A1013 W/MP953C1000	1/2"	4	VP526A1050	5/8"	2.5
FC2	4	VP526A1084	1/2"	1	VP526A1050	5/8"	2.5
FC3	1	V5013A1013 W/MP953C1000	1/2"	4	V5013A1023 W/MP953C1018	3/4"	6.3
FC4	1	V5013A1013 W/MP953C1000	1/2"	4	V5013A1013 W/MP953C1018	1/2"	4
FC5	1	VP526A1084	1/2"	1	VP526A1100	1/2"	1
FC6	2	VP526A1084	1/2"	1	VP526A1050	5/8"	2.5
FC7	1	V5013A1013 W/MP953C1000	1/2"	4	V5013A1013 W/MP953C1018	1/2"	4

FAN COIL UNIT CONTROL

TYPICAL OF ELEVEN

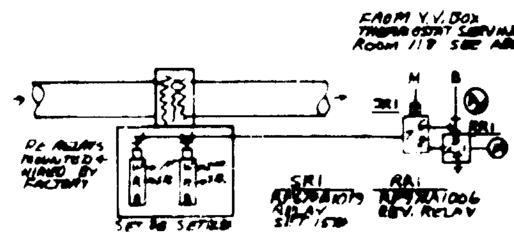


VARIABLE VOLUME BOX CONTROL



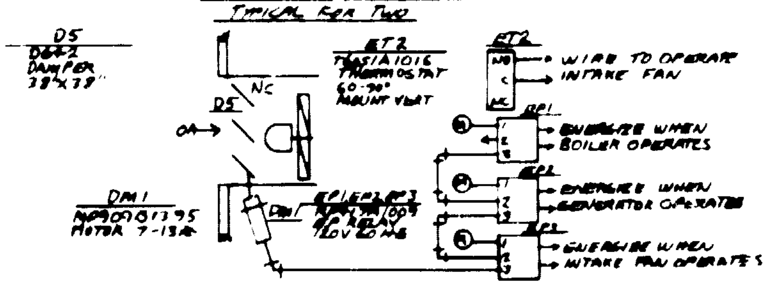
ELECTRIC REHEAT COILS

TYPICAL FOR TWO

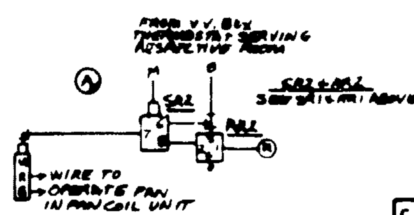


ELECTRIC REHEAT COIL RM 118 & 120

TYPICAL OF TWO

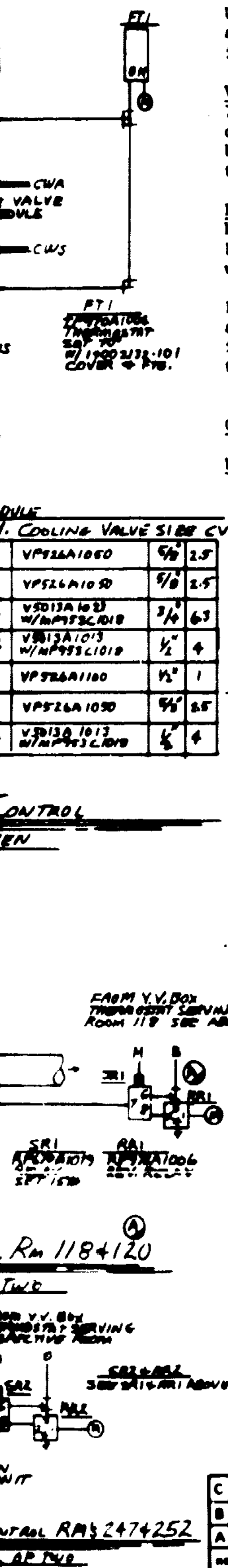


BOILER ROOM INTAKE CONTROL



UNIT HEATER CONTROL RMS 247 & 252

TYPICAL OF TWO



SEQUENCE OF OPERATION

Unit Heater Control When hot water is available as determined by the aquastat, the space thermostat cycles the unit heater fan to maintain its setting.

Variable Volume Box Control When the supply air to the V.V. box is above 72° the space thermostat operates reverse acting to open the box damper on a drop in space temperature. Anytime the supply air temperature is below 72°, the space thermostat opens the box damper on a rise in temperature.

Electric Reheat Coil The space thermostat energizes the stages of electric heat in sequence on a fall in space temperature. The reheat coil for Room 118 is operated by the variable volume box thermostat for that room when it is in the heating mode and is locked out.

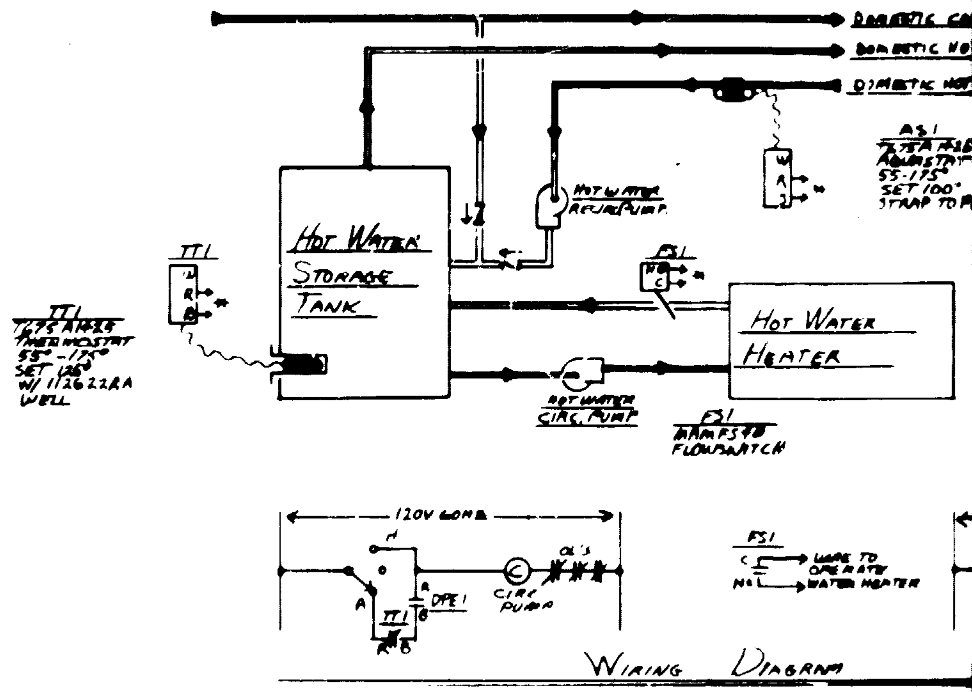
Boiler Room Intake Control The intake fan is cycled on by the thermostat anytime the space temperature rises above the thermostat setting. The intake damper opens whenever the intake fan runs, the boiler operates, or the generator runs.

MATERIAL LIST

Qty.	Part No.	Description
Unit Heaters		
14	T6051A1016	Thermostat
14	L6076B1023	Aquastat
V.V. Boxes		
3	TP970A1004	Thermostat
3	AK3996	Bracket
3	RP471A1002	Relay
4	TP972A1002	Thermostat
4	14002132-101	Cover
Electric Reheat Coils		
2	TP970B1002	Thermostat
2	14002132-101	Cover
1	RP670A1019	Relay
Boiler Room Intake		
1	D642	Damper
1	MP909B1395	Motor
1	T6051A1016	Thermostat
3	RP417A1009	E.P. Relay
Fan Coils		
11	TP970A1004	Thermostat
11	14002132-101	Cover
7	VP526A1084	Valve
7	VP526A1050	"
1	VP526A1100	"
Assembled valves consisting of:		
4	V5013A1013	Valve
4	MP953C1018	Operator
2	V5013A1013	Valve
2	MP953C1018	Operator
1	V5013A10??	Valve
1	MP953C1018	Operator

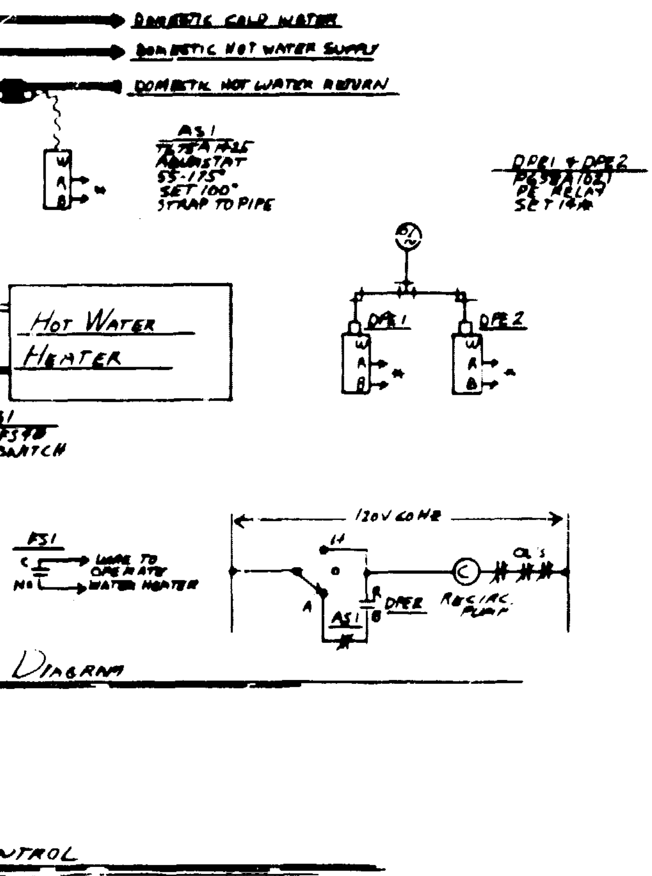
HONEYWELL

C				MISC CONTROLS
B				COLUMBUS TECHNICAL INSTITUTE
A	AS BUILT	3-16-79	RCN	
REVISIONS		DATE	APPD	
SUPERSEDES	DRAWN BY RCN	DATE MAY 4 1978	DRAWING NUMBER 951-77050	REV
SUPERSEDED BY	APPROVED BY RCN	SHEET 8 OF 10		A



Domestic Hot Water Control

* SEE WIRING DIAGRAM



SEQUENCE OF OPERATION

Domestic Hot Water Control When the storage tank temperature drops to 125° the circulating pump runs and the hot water heater is energized when the flow switch senses circulation.

The re-circulating pump is cycled to maintain the setting of the return water aquastat. The pumps and the hot water heater are off during the building "unoccupied" cycle.

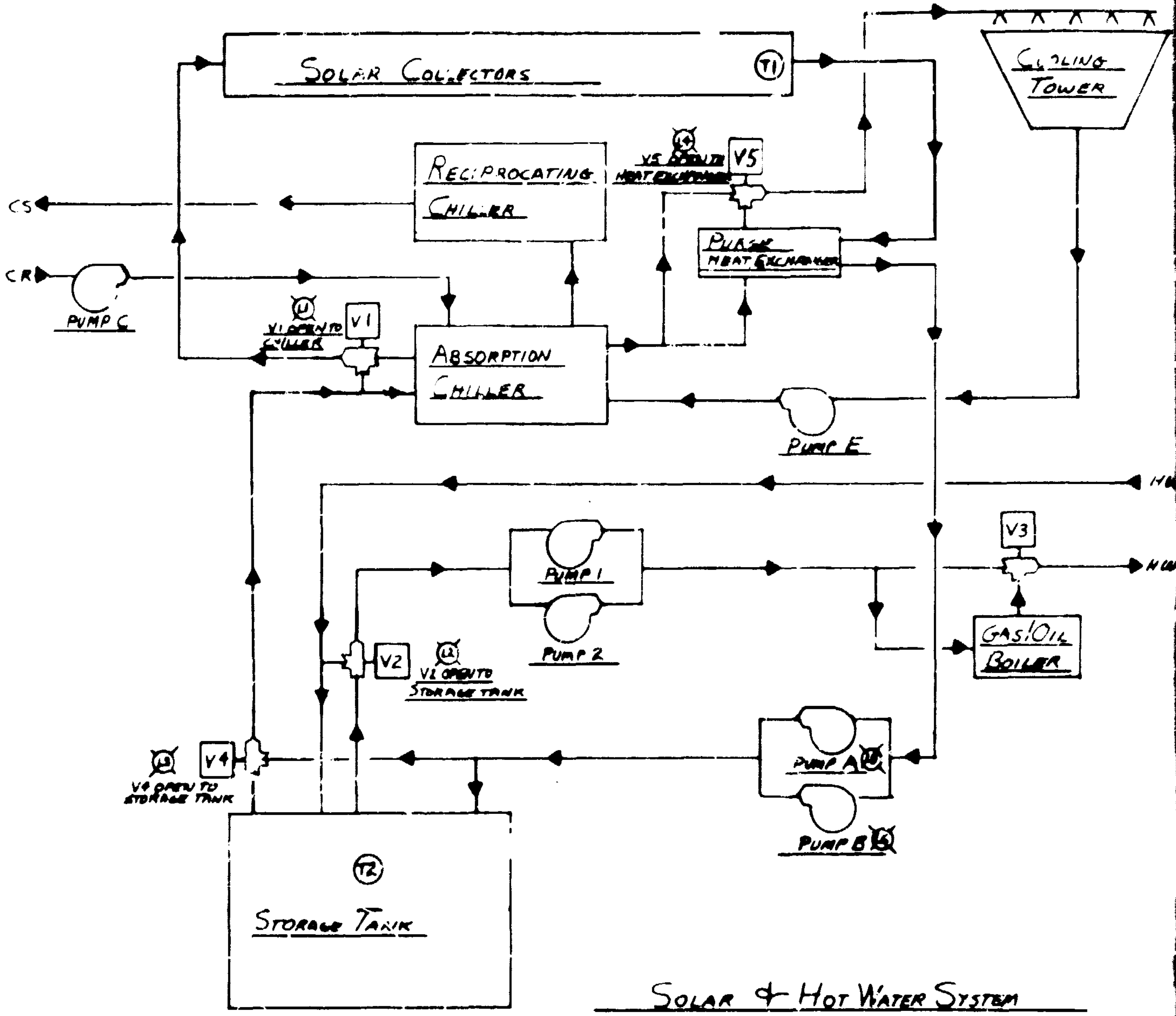
MATERIAL LIST

Qty	Part No.	Description
2	T675A1425	Aquastat
1	MAMFS43	Flow Switch
2	P658A1021	P.E. Relay

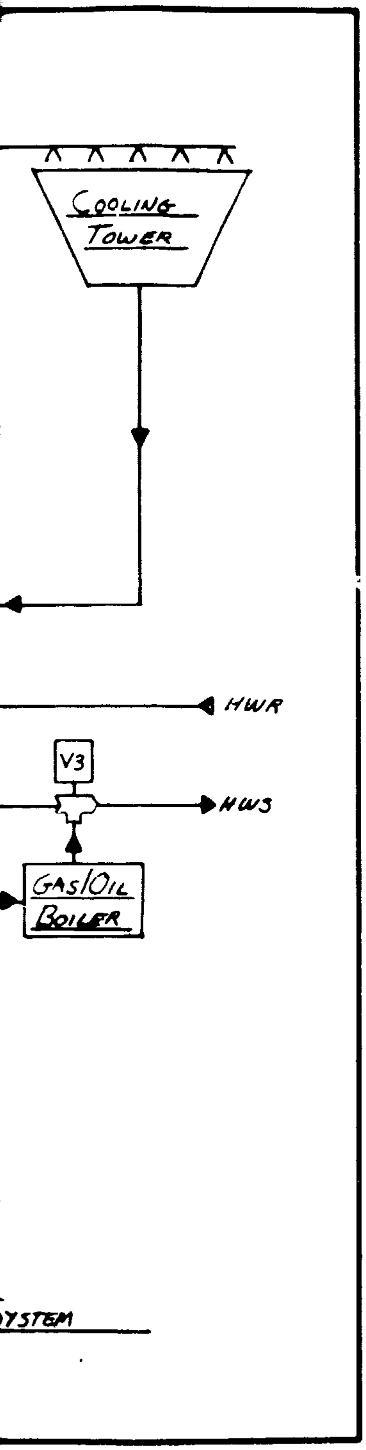
FOLDOUT FRAME

HONEYWELL

Domestic Hot Water Control			
Columbus Technical Institute			
Drawn by: RCN	Date: May 8 1978	Drawing number: 951-77050	
Approved by: RCN	Sheet 9 of 10		



SOLAR & HOT WATER SYSTEM

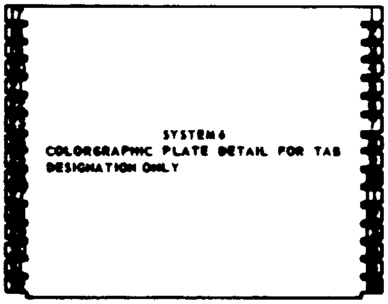


WHEN PREPARING THIS FORM, FIRST BLACKEN IN, WITH PENCIL, THE GENERAL OUTLINE LIMITS OF THE TYPE OF GRAPHIC REPRESENTATION (SUCH AS A SLIDE, COLORGRAPHIC PLATE, OR SUPERVISORY DATACENTER MODULES). THEN BLACKEN IN THE DIAGRAM LINES REPRESENTING THE OUTLINE OF THE SPECIFIC GRAPHIC LAYOUT REQUIRED.

FOR GRAPHIC MODULE SKETCH, USE ENTIRE AREA AS OUTLINED SCALE – 2 3 1

... SYSTEM 6 COLORGRAPHIC PLATE, USE AREA WITHIN DASHED LINES ONLY & DESI[illegible] DESIRED TAB LOCATION ON DETAIL BELOW SCALE – FULL

FOR TEMPORARY & PERMANENT FILM STRIP & SLIDES, USE AREA WITHIN DOTTED LINES ONLY



CHANGES	DESCRIPTION	BY	DATE
F			
E			
D			
C			
B			
A			
REV	DESCRIPTION	BY	DATE

PANEL TCP 1
C951-77050 SHEET 10 OF 10

GRAPHIC NO. 1 OF 1
PANEL SECTION NO. ____

JOB		
DATE	..D. BY	
SCALE	APP'D BY	

JOB NAME COLUMBUS TECH. INST
P.O. NO.
☐ FAB ☐ GRAPHIC MD
☐ FAB GRAPHIC SHEET OF

APPENDIX D

SOLAR DATA ACQUISITION & REDUCTION SYSTEM, REMTECH

OPERATIONAL MANUAL AND USER'S GUIDE FOR SOLAR DATA ACQUISITION AND REDUCTION (SDAR) SYSTEM

September, 1979

REMTECH, Inc.
2603 Artic Street, Suite 21
Huntsville, Alabama 35805
(205) 536-8581

FOREWORD

This manual provides information for the operation of a computer based data acquisition and reduction system. This system was developed under contract to Columbus Technical Institute, Columbus, Ohio, 43215. The cognizant administrative and procurement contact at Columbus Technical Institute was Mr. Russell W. Jordan, Administrative Assistant to the President. Technical direction for this system was provided by Mr. Dick Pearson and Mr. Rick Pavlak of Heapy and Associates, Dayton, Ohio, 45402. Development and assembly of the system at REMTECH was under the direction of Mr. Jim Levie and Mr. Gene Fuller.

TABLE OF CONTENTS

Section 1.0

INTRODUCTION

This document provides all the information needed to understand and interface with the microprocessor based data acquisition and reduction system. The system is referred to as the SDAR which stands for Solar Data Acquisition and Reduction. This name is descriptive of both the application and the function of the system.

A schematic of the system arrangement is shown in Fig. 1. The system is built around a Digital Equipment Corp. (DEC) LSI#11/2 general purpose 16 bit microcomputer processor module. With the use of this CPU, the system requires no operator intervention or programming on power up. The added computational power and speed which results from the extended instruction set found in 16 bit machines allow 32 bit floating point single precision calculations and English language commands for system manipulations. The system will interrogate up to 32 signal ended analog inputs at programmed intervals, convert the voltage measured to engineering units, calculate heat flows through the system, display the results on a video monitor, and log system parameters on a cassette tape. The system has been installed and programmed to provide performance data on the solar system installed on the administrative building at Columbus Technical Institute. The solar system consists of 4,000 ft^2 of evacuated tube collectors designed to provide 70% of the building's heating and 35% of the building's cooling (absorption in series with electric chiller).

The SDAR will provide continuous unattended operation and performance of its programmed tasks. Access to the system is available either by the display lobby terminal or by terminal access via telephone line modem.

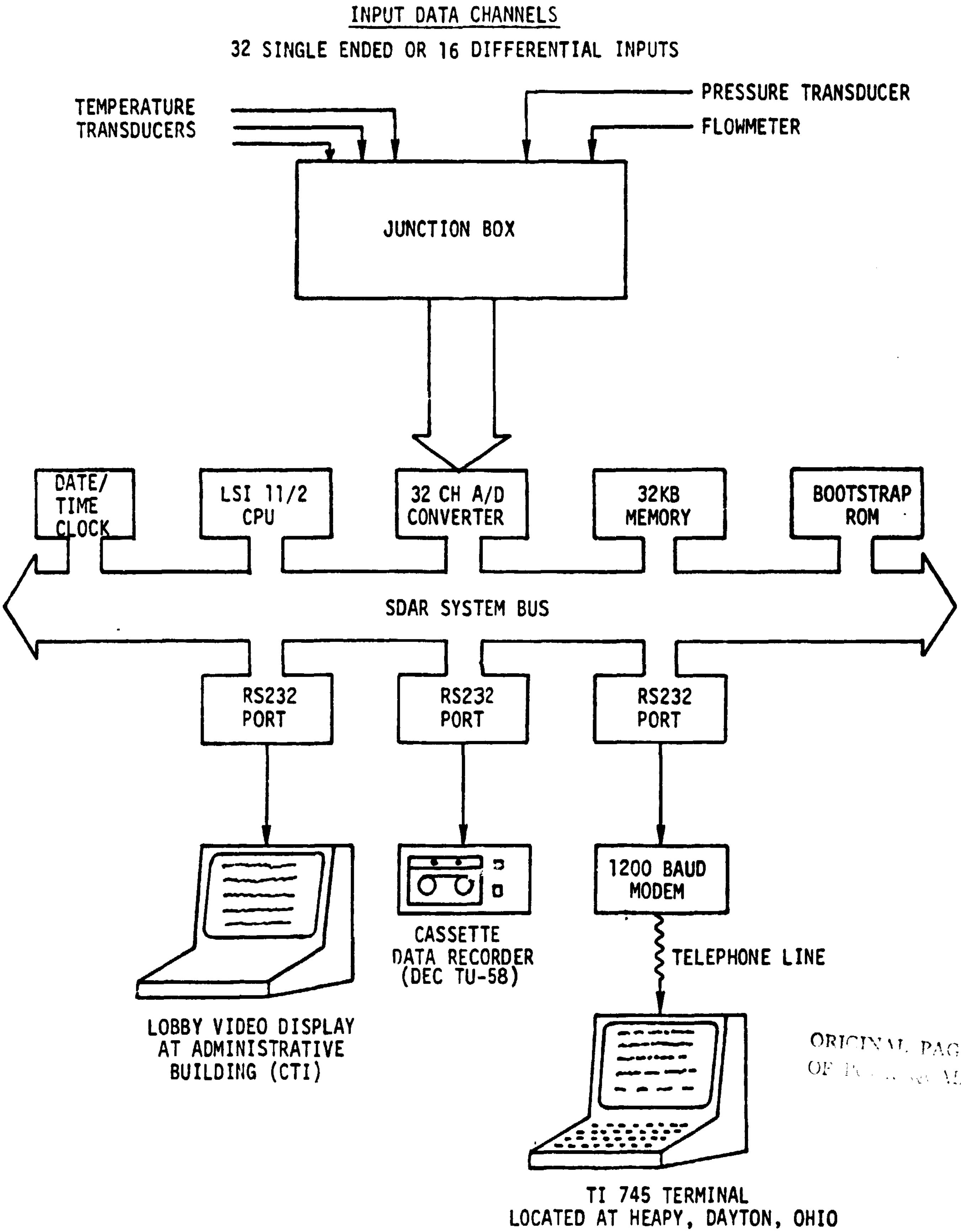


Fig. 1 Schematic of Site Data Acquisition and Reduction (SDAR) System for Columbus Technical Institute (CTI)

The remaining sections provide more detailed descriptions of the hardware and software, along with specific step-by-step instructions for data retrieval and other allowable system operational inquiries and changes.

Section 2.0

SCOPE OF WORK

The SDAR system was designed, constructed, and programmed to provide Columbus Technical Institute with an instrumentation package for solar energy heating and cooling that performs the following functions:

1. System allows for at least 32 analog inputs to measure temperature and flow rates as shown in Heapy and Associates drawing SM-1 and 2 for the Solar Monitoring System for Columbus Technical Institute.

2. System uses information collected to calculate and return energy data in engineering units (BTU, °F, etc.).

3. System records information on a magnetic tape recorder.

4. System is accessible by remote telecommunication device (Hard Printer Terminal) thru a telephone modem.

5. System has an information display that changes to display the last recording periods' information.

6. System provides as a minimum the following information:
   (a) BTU's available
   (b) BUT's used for cooling
   (c) BUT's of cooling by each chiller
   (d) BTU's used for heating
   (e) BTU's of heating by boiler
   (f) BTU's put in storage
   (g) Total BTU's used or stored

   In addition, other information is provided as may be derived from the points monitored.

Section 3.0

HARDWARE CONFIGURATION

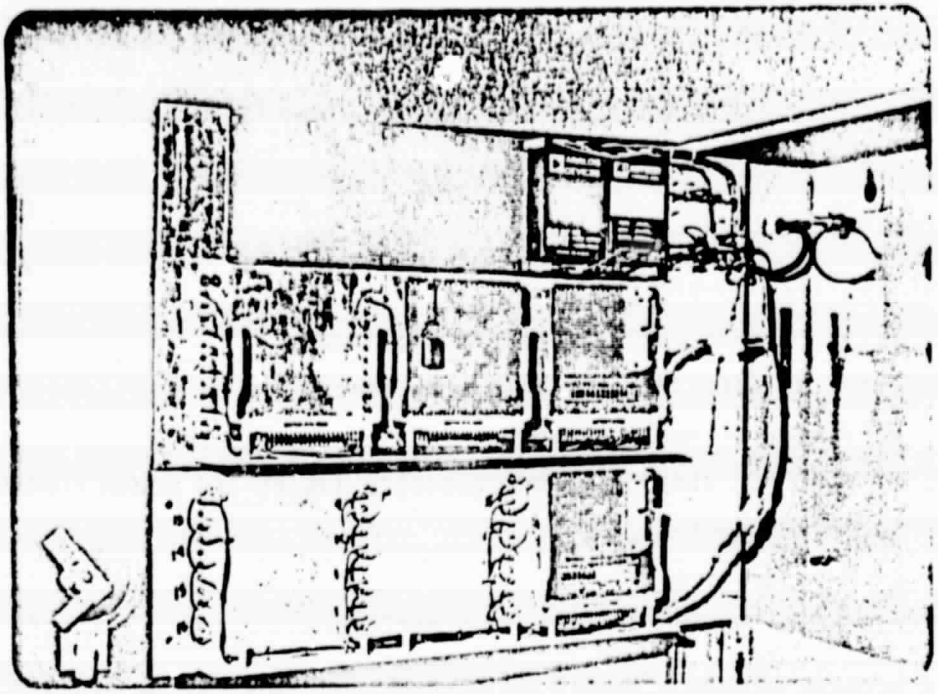
The SDAR consists of (See Fig. 1)

DEC LSI 11/2 16 bit processor
32KBytes of semiconductor read/write memory
32KBytes of semiconductor read only memory
32 differential analog inputs
RS232 port for video monitor, cassette logger and modem control
Non-volatile system clock
Lobby display terminal
Signal conditioning and junction enclosure

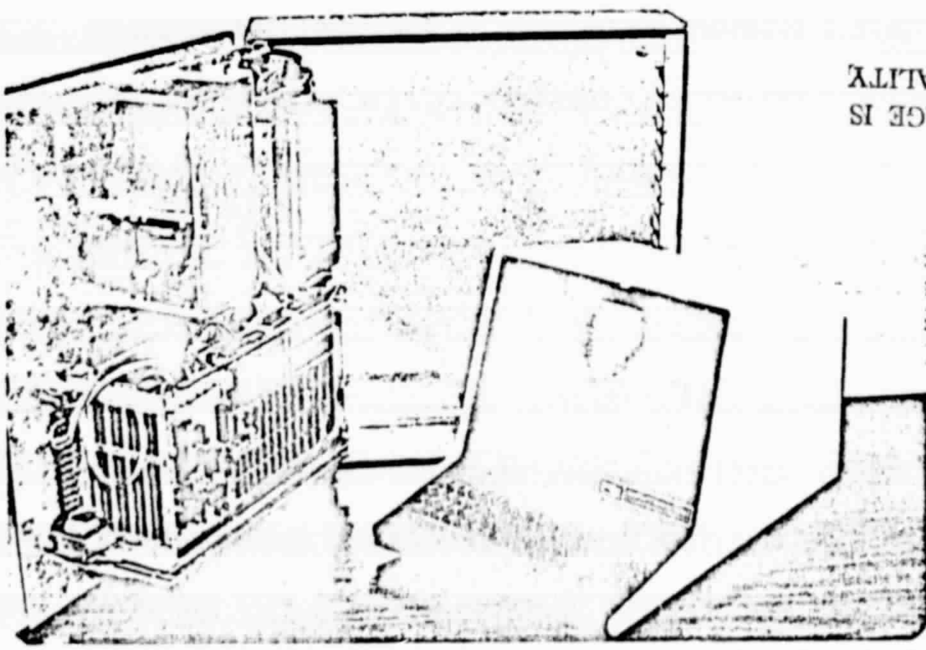
The SDAR is mounted within a NEMA 1 enclosure and requires normal 110 VAC power. A companion NEMA 1 enclosure junction box is used to terminate all input channels and to provide transducer power and signal conditioning for turbine flow meters. Figure 2 provides photographs of the completed hardware.

The video display monitor is a standard 24 line by 80 column CRT. It allows system parameters to be displayed, and if desired, may be used to interact with the SDAR in the same manner as a remote terminal. A 300 baud modem with remote dial-up capability is provided to allow access to the SDAR from a remote terminal. This modem does not require special telephone lines. Also provided is a cassette data storage medium (Digital Equipment Corp. TU-58) allowing off-line storage of 145,000 ASCII characters or 29,000 data records.

The analog to digital system used in the SDAR can accommodate up to $\pm$ 30V of common mode noise. The system clock is nonvolatile and will run on its internal rechargable battery for a minimum of 30 days before loosing its data. No battery back up is required for the SDAR in this installation. If power failure



Interior of Terminal/Signal Conditioning Enclosure



Interior of Computer Enclosure and Lobby Display Terminal

Fig. 2 Physical Appearances of SDAR Enclosures and Terminal.

should occur, the SDAR will automatically reboot and reload, and continue its programmed tasks when power is restored. This is accomplished without operator intervention.

Section 4.0

SYSTEM SOFTWARE

Descriptions are provided here of the general software arrangement and the specific software which provides access to the system operation. Step by step descriptions are provided to allow an operator the ability to easily and successfully interface with the system.

4.1 General Descriptions

All application software is contained on a 15K word PROM/BOOTSTRAP board. The software was developed on REMTECH's PDP11V03 minicomputer using high level languages (FORTRAN, MACRO-11) and loaded into PROM (Programable Read Only Memory). This allows the applications software to be tailored to the user's needs in a cost effective manner and allows a wide range of SDAR options to be implemented initially or at a later data. Some of the optional functions available include:

- Dual Disc Drive with RT11 Operating System
- Additional Analog Inputs
- Digital or Analog Control Signals
- Control Alarms and System Status Indicators
- Graphics Display Systems
- Hardcopy Plots
- Hardcopy Printouts
- Standard 9 Track Tape for Data Storage

These options are not included in the configuration provided since the specifications did not require these options.

Since the software is contained in ROM (Read Only Memory) the system will, following power up, automatically conduct processor and memory diagnostics, load, and begin execution of the program. When the program is loaded, a set of default values are also loaded which specify the channels and constants to be used for calculation of system heat flows and temperatures, the data channels to be monitored and the sampling frequency (normally 1 minute). These defaults can be changed by an operator at any time through the modem interface or the lobby terminal.

An operator can, via a remote terminal or the lobby terminal, call the SDAR and perform certain program manipulations. When called, the SDAR acknowledges the call and requests a password. When the correct password has been received, a menu of tasks is presented. By choosing tasks from the menu the operator can make changes in the SDAR's operations, such as; changing the constants used in heat flow calculations, resetting the date and time kept by the system clock, changing the recording interval, or dumping the data from the data cassette to the remote or lobby terminal. By implementing these programming tasks under SDAR control as a menu, the necessity for highly trained operators is eliminated and the possibility of operator induced malfunction is eliminated. This is unlike other systems which must be programmed before use and are thereby subject to time consuming and costly program development and debugging procedures with possible operator induced program failure. Since all dialog between the operator and the SDAR is in an English language form, the possibilities for error are further reduced. In addition, the SDAR software conducts extensive checks to determine the validity of the operator commands and to insure that any numerical input data is within a reasonable range.

4.2 Specific Software and System Operation

As presently configured, the SDAR will scan and convert to engineering units the 23 channels of data listed in Table 1. Using this data,along with the input system constants of Table 2, calculations of the system performance parameters listed in Table 3 are also performed. These scanning and calculating functions are performed at one minute intervals. The selected information shown in Fig. 3 is updated each minute with the new scan calculations and displayed to the lobby terminal,in order to inform the public on a real-time basis of the solar system's operational status and energy and monetary savings. As far as possible, the performance calculations and system nomenclature in Tables 1 - 3 have been made in accordance with the standards used by the National Solar Data Network as defined by the National Bureau of Standards Report, 76-1137, "Thermal Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program." This allows for easier data comparisons with other systems.

A user selected recording interval of from 1 to 59 minutes, instructs the SDAR to record to tape a date/time group, each of the 23 channel calculations, and the 19 system performance calculations at the selected recording interval. At the end of each 24 hour period a record summarizing the system's performance for that period is written to the system tape for use by the lobby display module.

Periodically, the SDAR will poll both the lobby display terminal and the remote terminal connection to determine if access is required to the system. When an active terminal is detected the SDAR will issue a password request. The lobby display CRT is considered active when the "ONLINE/OFF LINE" switch is

Table 1

INPUT CHANNEL ASSIGNMENTS
(September 1979)

Channel	Sensor	Variable	Function
1	I1	I001	Incident solar energy
2	T15	T001	Outdoor air temperature
3	T6	T100	Collector inlet/Absorbtion chiller outlet
4	T1	T101	Collector outlet/Purge inlet
5	T12	T102	Purge outlet
6	R1	S100	Collector pump status
7	T2	T200	Storage tank temperature
8	T7	T400	Storage outlet/Boiler inlet
9	T3	T401	Heating loop return
10	T8	T402	Boiler outlet
11	T4	T403	Heating loop supply
12	R2	S400	Heating loop pump status
13	R3	S401	Boiler status
14	FM1	W400	Heating loop flow rate
15	T11	T500	Absorbtion chiller inlet
16	T14	T501	Cooling loop return/Absorbtion chiller load inlet
17	T9	T502	Absorbtion chiller load outlet/Electric chiller inlet
18	T10	T503	Cooling loop supply/Electric chiller load outlet
19	T13	T504	Cooling tower inlet
20	T5	T506	Cooling tower outlet
21	R4	S500	Cooling loop pump status
22	R5	S505	Absorbtion chiller status
23	R6	S506	Electric chiller status

Table 2

REQUIRED SOLAR SYSTEM CONSTANTS*

AREA	- Collector area -(3507.2 sq. ft.)
W100	- Collector loop flow rate -(60 GPM)
EP101	- Collector pump operating energy -(11.5 KW)
W400	- Flowmeter conversion data -(1 pulse/10 gal 350 max - 100 min)
EP400	- Heating loop pump operating energy -(31 KW)
W500	- Cooling loop flow rate -(300 GPM)
EP500	- Cooling loop pump operating energy -(15.5 KW)
EP504	- Cooling tower operating energy used by absorption chiller -(3.46 KW)
EP505	- Absorption chiller operating energy -(3.8KW)
W505	- Absorption chiller load flow rate -(1606 GMP)
W506	- Electric chiller load flow rate - (3006 GPM)
HTCOST	- Cost per Btu of conventional heating-($7.49/1 x 10^6BTU)
CLCOST	- Cost per But of conventional cooling-($2.00/1 x 10^6BTU)
MININ	- Insolation required for useful solar collection -(20 BTU/sq.ft.)

* Data in ( ) are the constants in program supplied on September 1979. These constants may be changed by the use of Task 4 in the SDAR System Task List.

Table 3

SYSTEM PERFORMANCE CALCULATIONS

Solar energy available:	$Q001=\int I001\cdot AREA\cdot dt$
Solar energy collected:	$Q100=\int (T101-T100)\cdot W100\cdot S100\cdot dt$
Solar energy purged:	$Q101=\int (T101-T102)\cdot W100\cdot dt$
Solar collector operating energy:	$Q102=\int EP101\cdot S100\cdot dt$
Collector efficiency:	$N100=(Q100/Q001)$
Solar energy to storage:	$Q200=Q100-Q101-Q500$
Solar energy to heating load:	$Q400=Q402-Q401$
Auxiliary energy to heating load:	$Q401=\int (T402-T400)\cdot W100\cdot S401\cdot dt$
Heating load:	$Q402=\int (T403-T401)\cdot W400\cdot S400\cdot dt$
Solar heating loop operating energy:	$Q403=\int EP400\cdot (S400-S401)\cdot dt$
Solar energy to absorption chiller:	$Q500=\int (T500-T100)\cdot W100\cdot S505\cdot dt$
Cooling load:	$Q502=\int (T501-T503)\cdot W500\cdot S500\cdot dt$
Absorption chiller operating energy:	$Q503=\int (EP500+EP504+EP505)\cdot S505\cdot dt$
Absorption chiller load:	$Q505=\int (T501-T502)\cdot W505\cdot S505\cdot dt$
Electric chiller load:	$Q506=\int (T502-T503)\cdot W506\cdot S506\cdot dt$
Absorption chiller coefficient of performance:	$N500=Q505/(Q503+Q102)$
Energy saved:	$Q606=Q400+Q500-Q102-Q403-Q503$
Dollars saved:	$D606=\left(Q400-Q403-(Q102\cdot Q400)/(Q400+Q500)\right)\cdot HTCOST+\left(Q500-Q503-(Q102\cdot Q500)/(Q400+Q500)\right)\cdot CLCOST$
Hours of useful solar energy:	$S001=\begin{cases}0.0 \text{ if } I001<MININ\\ 1.0 \text{ if } I001>MININ\end{cases}$ $H001=\int S001\ dt$

```
26 AUG 79     11:30 A.M.
                                   ENERGY SAVED
YESTERDAY                1.232E+05 Btu                           $  100.00
LAST 30 DAYS             3.002E+06 Btu                           $ 1000.00
LAST 365 DAYS            9.079E+07 Btu                           $ 1000.00
*********************************************************************************
                          USEABLE SOLAR ENERGY AVAILABLE
YESTERDAY                10.2 Hours
LAST 30 DAYS            261.6 Hours
LAST 365 DAYS          1257.3 Hours
*********************************************************************************
                                 SYSTEM PARAMETERS
COLLECTOR INLET TEMPERATURE                                 178.9 F
COLLECTOR OUTLET TEMPERATURE                                200.5 F
STORAGE TANK TEMPERATURE                                    179.0 F
OUTDOOR AIR TEMPERATURE                                      66.2 F
SOLAR INTENSITY                                              88.2 Btu/sq Ft Hour
COLLECTOR PUMP ON
BOILER OFF
SOLAR CHILLER OFF
ELECTRIC CHILLER OFF
*********************************************************************************
```

Fig. 3 SDAR Display on Lobby Terminal

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in the "ON LINE" position. The modem and telephone line interface becomes active if the modem has been called. The call will prompt the modem to indicate to the SDAR that the remote terminal line has become active. When either of these terminals become active, the SDAR will respond with a password request. If the correct password is not received by the lobby terminal or modem terminal within 30 seconds, the SDAR resumes its normal mode of scanning channels, performs calculations, etc.

There are two possibilities with this access procedure that can cause difficulties with the SDAR operation. The first possibility is that the switch on the lobby terminal is turned to "on line" position accidently or remains in the "on line" position for an extended period. If this occurs, the SDAR will continue to display and update information to the terminal, however, the keyboard will be "live," and therefore characters can be typed to the display, thus, scrambling the display. This scrambled display does not affect the SDAR's assigned software operations. However, with the terminal switch in the "on line" position, the modem/remote terminal will be unable to call the unit. The obvious remedy for this problem is to turn the "on line" switch off.

Another system difficulty can occur if the SDAR is called by the remote/ terminal and access is obtained but not returned to the SDAR data collection program. In this case, the SDAR has essentially become non-functioning in that the data collection routine is not being performed. As defined below, the method for correcting this problem is to envoke Task 6 of the System Task List which allows for return of the program to data collection.

As indicated above, when an active terminal is detected by the SDAR a password request is issued to the terminal user. A valid password must be keyed in by the terminal user within 30 seconds. If the password is not received by

the SDAR it will return to its normal data acquisition mode and will not acknowledge the terminal again until it has been off line for at least one minute. The user should recall the system by telephone modem after one minute or reset the "on line" switch in order to obtain a new opportunity to enter a password.

The system password which allows access to the system task list is

SDARMANGR

which stands for Solar Data Acquisition and Reduction Manager.

After the above password has been received the SDAR will print the SYSTEM TASK LIST at the terminal and wait for the operator's response. Examples of the implementation of each task are provided on the following pages. The examples illustrate the messages which an operator will see displayed when implementating each task. The symbol ">" on the display indicates that the SDAR is waiting for an acceptable response from the operator before it proceeds.

NOTE:

> While the SDAR is performing operations in the system task list, none of the programmed system data acquisition and computation functions will be performed. For this reason, the historical computations will be inaccurate, if the use of the system task lists are utilized for large periods of time. To minimize these inaccuracies it is recommended that access to the Task List be made during periods when there is minimum solar and/or total HVAC system activity.

TASK 1 - DATA TAPE CHANGE

```
ENTER PASSWORD >SDARMANGR(Note - the password will not be printed)
VALID PASSWORD RECEIVED - WAIT


 2 AUG 79    22:25


        SDAR SYSTEM TASK LIST

          1   Data Tape Change
          2   Real Time Data List
          3   List Recorded Data
          4   Change Constants
          5   Reset System Clock
          6   Return To Data Collection Program
```



```
Enter the task number to be executed >1
DATA TAPE CHANGE-
Drive #1 Tape Change - Are you sure?(Y/N) >Y
Ready for tape change - Type 'F' when done.>F
WAIT
```

NOTES: Task 1

1. Drive #1 is the right hand drive unit when facing the SDAR.

2. Only the data tape in Drive #1 should be replaced.

3. The system program tape in Drive #0 should not be removed unless authorized by cognizant personnel.

4. See Section 5.1 for further explanation.

TASK 2 - REAL TIME DATA LIST

```
2 AUG 79    22:28

        SDAR SYSTEM TASK LIST

        1  Data Tape Change
        2  Real Time Data List
        3  List Recorded Data
        4  Change Constants
        5  Reset System Clock
        6  Return To Data Collection Program


nter the task number to be executed >2
EAL TIME DATA LIST-
nter the number of scans to be listed >2

2 AUG 79    22:28:36    Scan number-  1

001/CH01                  T001/CH02  T100/CH03  T101/CH04  T102/CH05  S100/CH06  T200/CH07
296.5Btu/sqFt/Hr           59.6 F     97.8 F    155.3 F    123.7 F      1.0 S    100.2 F

400/CH08  T401/CH09  T402/CH10  T403/CH11  S400/CH12  S401/CH13  W400/CH14
94.2 F      93.1 F   122.9 F    122.9 F      0.0 S      0.0 S      0.0 GPM

500/CH15  T501/CH16  T502/CH17  T503/CH18  T504/CH19  T506/CH20  S500/CH21  S505/CH22
    0 F     94.2 F     94.1 F     68.2 F     96.1 F     81.6 F      1.0 S      0.0 S

506/CH23
 1.0 S


2 AUG 79    22:28:54    Scan number-  2

001/CH01                  T001/CH02  T100/CH03  T101/CH04  T102/CH05  S100/CH06  T200/CH07
296.4Btu/sqFt/Hr           59.6 F     97.8 F    155.3 F    123.7 F      1.0 S    100.2 F

400/CH08  T401/CH09  T402/CH10  T403/CH11  S400/CH12  S401/CH13  W400/CH14
94.1 F      93.2 F   122.9 F    123.0 F      0.0 S      0.0 S      0.0 GPM

500/CH15  T501/CH16  T502/CH17  T503/CH18  T504/CH19  T506/CH20  S500/CH21  S505/CH22
22.0 F      94.0 F     94.1 F     68.2 F     96.1 F     81.6 F      1.0 S      0.0 S

506/CH23
 1.0 S
```

NOTES: Task 2:

1. Be careful in selecting the number of real time data scans desired. Since the SDAR data exchange rate is at 300 Baud, the exchange and printout of data can take longer than expected. Once the display of requested data has started it can not be stopped until completed.

```
2 AUG 79    22:29

        SDAR SYSTEM TASK LIST

        1  Data Tape Change
        2  Real Time Data List
        3  List Recorded Data
        4  Change Constants
        5  Reset System Clock
        6  Return To Data Collection Program


nter the task number to be executed >3
ECORDED DATA LIST-
ape starting Date/Time    2 AUG 79    18:05:00
ape ending Date/Time      2 AUG 79    19:10:00
ist data from this tape?(Y/N) >Y
nter starting Date(DD-MMM-YY) >02-AUG-79
AIT
nter ending Date(DD-MMM-YY) >02-AUG-79
AIT

2 AUG 79    18:05:00    Scan number-  1

0 /CH01            T001/CH02 T100/CH03 T101/CH04 T102/CH05 S100/CH06 T200/CH07
 0.0Btu/sqFt/Hr     59.3 F    97.5 F   123.3 F   123.5 F     0.0 S    99.5 F

400/CH08 T401/CH09 T402/CH10 T403/CH11 S400/CH12 S401/CH13 W400/CH14
93.9 F    92.9 F   122.7 F   122.5 F     0.0 S     0.0 S     0.0 GPM

500/CH15 T501/CH16 T502/CH17 T503/CH18 T504/CH19 T506/CH20 S500/CH21 S505/CH22
21.8 F    93.9 F    94.0 F    67.9 F    95.8 F    81.4 F     0.0 S     0.0 S

506/CH23
 0.0 S


001-Btu   Q100-Btu  Q101-Btu   Q102-Btu   N100-%     Q200-Btu
0.00E-01  0.00E-01  -3.35E+02  0.00E-01    00.0      3.35E+02

400-Btu   Q401-Btu  Q402-Btu   Q403-Btu
0.00E-01  0.00E-01  0.00E-01   0.00E-01

500-Btu   Q502-Btu  Q503-Btu   Q505-Btu   Q506-Btu   N500-%
0.00E-01  0.00E-01  0.00E-01   0.00E-01   0.00E-01    00.0

506-Btu   D606-$    H001-Hr
.00E-01       0.00      0.00
```

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```
2 AUG 79    22:30

         SDAR SYSTEM TASK LIST

         1  Data Tape Change
         2  Real Time Data List
         3  List Recorded Data
         4  Change Constants
         5  Reset System Clock
         6  Return To Data Collection Program


nter the task number to be executed >3
ECORDED DATA LIST-
ape starting Date/Time     2 AUG 79    18:05:00
ape ending Date/Time       2 AUG 79    19:10:00
ist data from this tape?(Y/N) >N
ATA TAPE CHANGE-
rive #1 Tape Change - Are you sure?(Y/N) >Y
eady for tape change - Type "F" when done.>F
AIT
ape starting Date/Time     1 AUG 79    18:05:00
ape ending Date/Time       1 AUG 79    19:10:00
ist data from this tape?(Y/N) >Y
nter starting Date(DD-MMM-YY) >1-AUG-79
n   id Date - Example: 21-JUN-79
nter starting Date(DD-MMM-YY) >01-AUG-79
AIT
nter ending Date(DD-MMM-YY) >01-AUG-79
AIT

1 AUG 79    18:05:00    Scan number-  1

001/CH01             T001/CH02 T100/CH03 T101/CH04 T102/CH05 S100/CH06 T200/CH07
  0.0Btu/sqFt/Hr      59.3 F    97.5 F   123.3 F   123.5 F     0.0 S    99.5 F

400/CH08 T401/CH09 T402/CH10 T403/CH11 S400/CH12 S401/CH13 W400/CH14
93.9 F    92.9 F   122.7 F   122.5 F     0.0 S     0.0 S     0.0 GPM

500/CH15 T501/CH16 T502/CH17 T503/CH18 T504/CH19 T506/CH20 S500/CH21 S505/CH22
21.8 F    93.9 F    94.0 F    67.9 F    95.8 F    81.4 F     0.0 S     0.0 S

506/CH23
 0.0 S


001-Btu   Q100-Btu  Q101-Btu  Q102-Btu  N100-%    Q200-Btu
0.00E-01  0.00E-01 -3.35E+02  0.00E-01   00.0     3.35E+02

400-Btu   Q401-Btu  Q402-Btu  Q403-Btu
0  0E-01  0.00E-01  0.00E-01  0.00E-01

500-Btu   Q502-Btu  Q503-Btu  Q505-Btu  Q506-Btu  N500-%
0.00E-01  0.00E-01  0.00E-01  0.00E-01  0.00E-01   00.0
```

NOTE: This sequence illustrates the insertion of a previously recorded data tape for extraction of data for system analysis.

```
Q606-Btu  D606-$    H001-Hr
 0.00E-01      0.00      0.00

Do not forget to reinstall the current data tape
```

NOTES: Task 3

1. Be careful in selecting the number of real time data scans desired. Since the SDAR data exchange rate is at 300 Baud, the exchange and printout of data can take longer than expected. Once the display of requested data has started it can not be stopped until completed.

2. Descriptions of the parameters and channels are provided in Tables 1-3.

TASK 4 - CHANGE CONSTANTS

```
2 AUG 79     22:36

        SDAR SYSTEM TASK LIST

        1  Data Tape Change
        2  Real Time Data List
        3  List Recorded Data
        4  Change Constants
        5  Reset System Clock
        6  Return To Data Collection Program


Enter the task number to be executed >4
W100(Gpm)=       60.00>
EP101(Kw)=       11.50>
EP400(Kw)=       31.00>
W500(Gpm)=      300.00>
EP500(Kw)=       15.50>
EP504(Kw)=        3.46>
EP505(Kw)=        3.80>
W505(Gpm)=      160.00>
W506(Gpm)=      300.00>
HTCOST($/MBtu)=  7.49>
CLCOST($/MBtu)=  2.00>
MININ(Btu/sqFt)= 20.0>
Record Intvl(Min)= 59>30
```

NOTES: Task 4

1. Tables 2 and 3 provide descriptions of how the engineering constants are used in the system performance calculations.

2. The recording interval constant may be selected to be from 1 to 59 minutes in whole minute increments. See Section 5.1.1 on how the recording interval affects the frequency of tape changes.

TASK 5 - RESET SYSTEM CLOCK

```
2 AUG 79    22:37

          SDAR SYSTEM TASK LIST

          1  Data Tape Change
          2  Real Time Data List
          3  List Recorded Data
          4  Change Constants
          5  Reset System Clock
          6  Return To Data Collection Program


Enter the task number to be executed >5
CLOCK CHANGE - Enter the new date(DD-MMM-YY) >2-AUG-79
Invalid Date or Time entered - Example: 21-JUN-79
                                         14:31

CLOCK CHANGE - Enter the new date(DD-MMM-YY) >02-AUG-79
Enter the new time in 24Hr clock(HH:MM) >22:45
Clock now reads -  2 AUG 79    22:45:00
```

TASK 6 - RETURN TO DATA COLLECTION PROGRAM

```
2 AUG 79    22:45

        SDAR SYSTEM TASK LIST

        1  Data Tape Change
        2  Real Time Data List
        3  List Recorded Data
        4  Change Constants
        5  Reset System Clock
        6  Return To Data Collection Program


Enter the task number to be executed >6
Returning to data collection program.
Please hang up the modem or place the ON-LINE/OFF-LINE switch
in the OFF-LINE position.
```

NOTES: Task 6

1. Section 4.2 has further explanation of system problems that can be caused by not hanging up the modem or resetting the lobby display switch.

Section 5.0

OPERATIONAL INFORMATION

This section provides information considered necessary to achieve continued successful operation of the unit.

5.1 Cassette Tape Drive

The tape drive utilized in the SDAR is manufactured by Digital Equipment Corp. as their model TU-58 dual drive cassette unit. This unit is mounted in the SDAR enclosure and requires the use of two tape cassettes. The two tape drive slots are shown in Fig. 4 and are labeled as Drive Unit "0" and Drive Unit "1." Indicator lights are provided to indicate when the tape drive is in an active status, i.e., either reading or recording from tape.

NOTE:

> DO NOT remove the cassettes while the active indicator lights are illuminated. This may cause data to be lost. However, if removal does occur while the unit is active no physical damage will occur to the unit other than the possible data loss.

The cassette used at Drive Unit 0 contains the SDAR operating system and the cumulative solar system operating parameters that are periodically updated, averaged, and displayed to the lobby terminal. The cassette used at Drive Unit 1 contains the actual engineering data computed for each recorded scan.

NOTE:

> The tape cartridge in Drive Unit 0 should never be removed unless some change in the operating system is considered necessary. If such changes in the operating system are required, contact REMTECH for technical assistance.

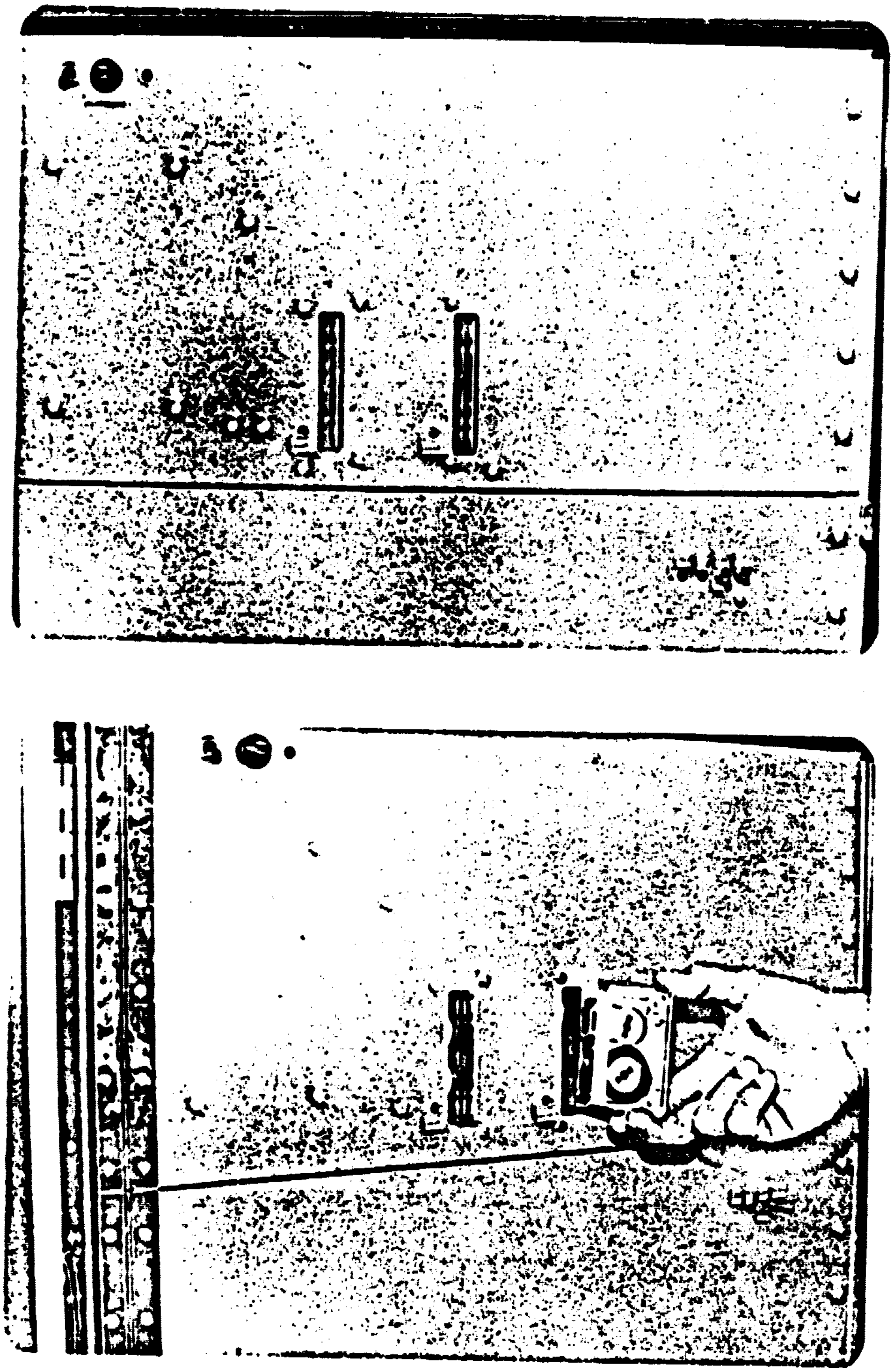


Fig. 4 Illustration of SDAR Tape Insertion and Controls

5.1.1 Tape Change Procedure

Periodically, the cassette in Drive Unit 1 must be changed if the engineering data recorded on that tape are to be retained for historical and/or system analysis purposes. The time interval between tape changes is a function of the amount of information that may be recorded on the tape and the frequency with which a recording is made. The cassette cartridges will allow 1880 recordings before becoming full of data.

As described in Section 4.2, the SDAR scans the 23 data channels (Table 1) at one minute intervals and converts these readings to engineering units. In addition, the program performs the 19 system performance calculations given in Table 3, so every minute 42 data records are available for recording. The interval at which data is recorded may be selected to be from 1 to 59 minutes in whole-minute increments.

Then depending on the recording interval selected, the requirements for tape changes will likewise vary. Guidelines for this variation are provided below.

Selected Recording Interval (Minutes)	Time to Fill Cassette Tapes (hours)	(days)
1	31.3	1.3
5	156.7	6.5
10	313.3	13.1
15	470.0	19.6
20	626.7	26.1
30	940.0	39.2
59	1848.7	77.0

It should be noted that if the recording interval is set at 10 minutes, the data read on the input channel assignments shown in Table 1 will not be recorded but once every 10 minutes even though the SDAR is performing that reading and calculation at one minute intervals. Likewise, the performance calculations of

Table 3 are only recorded every 10 minutes even though the calculation is made each minute. Thus, the selection of the recording interval must allow for both the requirements of the system performance analysis and the requirements for the frequency at which a tape change can be routinely made.

For example, if the recording interval is selected to be every 15 minutes, then replacement of the tape must be made every 470 operating hours or 19.6 days. The SDAR is also programmed to provide visual and audible alarm at the lobby display terminal when the tape is close to becoming full. When the tape becomes 80% full, a warning will appear on the lobby display alerting cognizant personnel of the need to change the tape. An audible beeping alarm will also be made each time the lobby display is updated.

NOTE:

> If the full tape is not replaced with a new one the SDAR will continue to read the data channels as programmed and perform the indicated calculations, however, the calculations will not be recorded to tape in proper sequence. The replacement tape for the SDAR is the Digital Equipment Corporation, DEC tape II which is a preformated version of the 3M Corp. DC100A tape cartridge.

5.1.2 Tape Head and Drive Cleaning

The tape head and drive require periodic cleaning to prevent data errors caused by contamination and oxide build-up. After 250 hours of tape running time or semi-annually, the tape head and drive wheel should be cleaned with a long handled cotton applicator moistened with 95 percent isopropyl-alcohol, fluorocarbon TF, 113 or equivalent. The drive wheel should be rotated to assure cleaning all around the surface.

5.1.3 Cassette Cartridge Wear

The tape cartridge is expected to last for 5,000 end-to-end-and back passes. Useful life may vary from tape to tape, however, if errors in the tape data begin

to occur it is recommended that the tape be discarded and a new one utilized.

5.1.4 Tape Drive Specifications

- Capacity per cartridge - 262,144 bytes, formatted in 512 blocks of 512 bytes each
- Read/write - 41.7 μs/data bit, 24k bytes/s
- Cartridge life - 5,000 minimum end-to-end tape passes
- Average access time - 9.3 seconds
- Maximum access time - 28 seconds
- Read/write tape speed - 76 cm/s(30in/s)
- Search tape speed - 152 cm/s (60 in/s)
- Read/write tape speed - 76 cm/s (30in/s)
- Recording method - Ratio encoding
- Medium - DECtape II cartridge with 42.7 m(140 ft) of 3.81 mm (0.150 in) tape
- Track format - Two tracks, each containing 1024 individually numbered, firmware-interleaved "records." Firmware manipulates 4 records at each operation to form 512-byte blocks.

5.2 SDAR Controls

As shown in Fig. 4, the SDAR enclosure contains several controls and indicator lights in addition to the slots for the tape cartridges. In the upper left corner an on-off switch, fuse and "on" indicator light is provided. On the lower right side of the unit two switches and indicator lights are provided. The "run" indicator light will be illuminated when the "run-halt" switch is in the run position. This indicates that the unit is in a run status and performing programmed functions. If the run-halt switch is moved to the halt position, the program will stop the performance of the programmed functions. The "DC ok"

indicator light indicates that the DC power supply is providing power to the computer circuits.

The "reset" switch allows for the operator to manually "boot" the system. Pushing this switch upward causes the unit to read the operating system tape in Drive Unit 0 and load the programmed information on that tape to its memory. The reset switch should only be used when it is necessary to replace and/or reload a new operating system to the SDAR. In the event of a power failure, it is not necessary to "reset" the unit, since the SDAR is programmed to "reboot" itself when power is restored.

NOTE

> It is recommended that only authorized and knowledgeable personnel have access to the interior of the SDAR enclosure. Once installed, none of the control switches should be moved since the changing of these switches can halt the unit in the performance of its programmed instructions.

5.3 Terminal/Signal Conditioning Controls

The only controls provided in the terminal/signal conditioning enclosure is the on/off switch for the unit and several voltage indicator lights. When properly operating, all the voltage and power indicator lights should be illuminated. Again, it is recommended that only authorized personnel have access to this unit since if the power is switched off, the system will not perform its prescribed functions.

5.4 System Power Requirements

The power requirements of three units to the SDAR system are:

	Voltage	Current Draw (amps)
SDAR Enclosure	110-115	3
Terminal/Signal Enclosure	110-115	3
Video Display	110-115	3

It is recommended that these units be placed on a separate 20 amp circuit which will not be interupted by normal electrical building maintenance. Power interuption will only cause the loss of data for the time interval over which the power is lost. When power is restored, the system will continue to perform its programmed function.

NOTE

> The loss of power for a period of longer than 30 days will require that an operator reset the system clock with the correct time since the internal battery back-up power supply will only maintain the system clock for 30 days.

5.5 SDAR Air Filter Cleaning

The SDAR unit contains two fans which provide cooling air to the enclosure circuits by drawing exterior air through it. A porous foam filter is located on the right hand side of SDAR enclosure. Periodic inspection and cleaning of this filter is recommended to maintain an adequate air flow through the system.

NOTE

> Periodic inspection and cleaning of the SDAR air filter is recommended to maintain an airflow through the system. Inspection of the filter should be made monthly for excessive lint build-up. If excessive lint build-up is noted, filter should be removed and cleaned. Every 3 months filter should be be removed and cleaned.

The filter may be removed by removal of the eleven screws holding the SDAR swing out panels in place. These screws are located along the right hand side of the SDAR panels. Five screws hold the top panel in place and six hold the bottom panel in place. Upon removal of these screws, the two panels can be swung out, allowing access to the filter. Four additional screws should be removed to allow the foam filter to be removed. Upon removal the filter should be washed in warm soapy water, dried and replaced in the enclosure.

NOTE

> While performing the filter inspection, personnel should also inspect the two fans to assure that each is operating. In the event that one is not operating, arrangements should be made to have REMTECH replace it or local on-site replacement can be made. Two fans were provided to allow for back-up in the event that one failed. Specified fan life is 10,000 hrs.

5.6 Warranty

All hardware components are warranted against defects in material and workmanship under normal and proper use and in their original, as delivered, unmodified condition for a period of 90 days from the initial delivery date. If found defective by REMTECH within the terms of this warranty REMTECH's sole obligation shall be to repair or replace (at its option) the defective components. If REMTECH determines that the component is not defective within the terms of this warranty, the customer shall pay all costs of handling and return transportation. All replaced components become the property of REMTECH.

All software supplied in compliance with the customer requirements is warranted for a period of 90 days against defects in performing the functions

specified. If found defective, REMTECH's sole obligation shall be to correct the defects to meet the customer requirements.

All work performed outside the scope of the above warranty periods will be at REMTECH's then current labor and materials rates.

APPENDIX E
ACCEPTANCE TEST PLAN, UDRI

COLUMBUS TECHNICAL INSTITUTE
SOLAR ENERGY DEMONSTRATION PROGRAM

FINAL

Acceptance Test Plan

University of Dayton
Research Institute

March 5, 1979

Reference Purchase Order No. 18679

Prepared for:

Columbus Technical Institute
550 East Spring Street
P.O. Box 1609
Columbus, Ohio 43216

FINAL ACCEPTANCE TEST PLAN

The equipment, inspection, and acceptance testing requirements for the solar system has been specified in the "Specification for Phase V Building" dated April 1977 and incorporating the latest revisions, to insure that all components and work are in accordance with all local, State, and Federal laws, ordinances, rules, and regulations relating to the work and to insure that all components, subsystems, and systems operate in conformance with the design specifications. The detailed acceptance test plan presented herein is based on the final approved working drawings and system control logic. This test plan includes eleven test conditions to functionally demonstrate the systems operational modes of solar energy collection and storage, heating and cooling, system leak detection, and system overheat and freeze protection.

A. ITEM TO BE TESTED

The item to be tested will include all parts of the operating and control systems. Specifically, the piping system, the pumps, the control transducers, the control actuators, and the system safety and warning components will be tested.

B. TEST OBJECTIVES

The objectives of the test program are to determine and demonstrate that the system is functionally operable, that it meets the design specifications, and that it is ready for use.

C. TEST REQUIREMENTS

1. All controls and operational components shall be exercised by inducing transducer signals or detector actuation. Functional operability to the design specifications shall be shown in each of the system's operational modes.

2. All solar system components, including piping and fittings, solar collectors, storage tank, and heat exchangers, shall be tested in the system at 45 psi,

30 psi for collectors. Leaks, if any, shall be made tight and retests performed until no discernible leaks are found.

3. Approximate flow rates shall be determined by measuring pressure drop through the various components, collectors, absorption machine, purge heat exchanger, etc., throughout the system under all modes of operation to determine that pumps are delivering design fluid flows and that obstructions are not present in the system and to verify that the system control valves are not leaking and are positioned for proper flow.

D. TEST PROCEDURES

1. The operation of the solar system in each of the operating modes shown in Table 1 shall be demonstrated by falsifying the various temperature transducer signals and actuating the leak detector switch as indicated in Table 2. A description of the solar control system and a schematic for locating components and directions of flow is presented in Attachment 1. The test sequence for the system in the drained and filled configuration is presented below. The test condition comments presented in Table 3 are summary in nature and are not intended to be all inclusive.

<u>Test Sequence - System Drained</u>
(see Tables 2 and 3)

- Set all equipment controls to "OFF."
- Set simulated test temperatures.
- Set building HVAC interface controls.
- Activate the flow alarm switch
- Check valve status - This should be accomplished by visual inspection to insure that the direction of flow is as indicated for the given test condition.

- Check equipment status by:
  - Momentarily switching the equipment controls to "AUTO" mode,
  - Measuring the availability of power to each equipment item.

Test Sequence - System Filled
(see Tables 2 and 3)

- Set all equipment controls to "OFF".
- Set simulated test temperatures.
- Set building HVAC interface controls.
- Activate the flow alarm switch.
- Check valve status - This should be accomplished by visual inspection to insure that the direction of flow is as indicated for the given test condition.
- Set all equipment controls to the "AUTO" mode
- Measure the flow rates and pressures in appropriate segments of the system as a final verification of the operation of the pumps and control system in accordance with the design specifications and that the system is free of obstrucations and that the system control valves are not leaking and are positioned for proper flow.
- Re-set all equipment controls to the "OFF" mode.

2. Pressure tests will be performed on all segments of the fluid system after installation is completed to demonstrate the integrity and safety of the system. Pressure relief valves will be replaced with plugs as necessary and each segment of the system will be pressurized to 150 percent of its design working pressure with the exception of the collectors, which will be tested at 100%, or 30 psig. The lack of necessity for makeup of the pressurizing fluid for ten minutes at this pressure shall demonstrate the integrity of the fluid system.

Satisfactory completion of these procedures will be deemed sufficient to demonstrate the adequacy of the system to meet its performance requirements.

TABLE 1

SYSTEMS FUNCTIONS DEMONSTRATED VERSUS TEST CONDITION NUMBER

Function Demonstrated	Test Condition Number										
	1	2	3	4	5	6	7	8	9	10	11
Solar Heat Collected			X	X	X	X					
Head Added to Storage Tank			X	X	X	X					
Building Heat- No Boiler Contribution					X		X				
Building Heat- Boiler Contribution								X	X	X	X
Building Cooling				X		X	X	X			
Heat Purged				X							
T1 < T2	X	X					X	X	X	X	X
TO < 40°F									X	X	X
T1 < 40°F										X	X
Low Collector Temperature T2 < 38°F											X
Solar System Leak		X									

TABLE 2

SIMULATED TEST CONDITIONS AND COMPONENT STATUS VERSUS TEST CONDITION NUMBER

	Test Condition Number										
	1	2	3	4	5	6	7	8	9	10	11
Temperature Time Settings											
T0 Outdoor Air Temp °F	70	70	75	75	50	75	60	60	35	10	10
T1 Collector Discharge °F	65	65	100	230	100	210	65	60	60	35	37
T2 Storage °F	70	70	80	200	90	190	90	65	65	65	37
T3 Heating System Return °F	70	70	75	75	80	80	70	70	70	75	75
T4 Heating System Supply °F	70	70	75	75	84	80	78	78	93	109	109
T5 Purge Discharge °F	65	65	100	210	100	210	65	60	60	35	37
T6 Collector Return	70	70	70	200	90	190	90	65	65	65	37
Valve Status											
V1 Absorption Machine	B.P.	B.P.	B.P.	M	B.P.	M	B.P.	B.P.	B.P.	B.P.	B.P
V2 Tank (Heating System)	T	T	T	T	T	T	T	B.P.	B.P.	B.P.	B.P.
V3 Boiler	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.	M	M	M	M
V4 Tank (Collector System)	B.P.	B.P.	T	T	T	T	B.P.	B.P.	B.P.	T	T
V5 Purge	B.P.	B.P.	B.P.	M	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.	B.P.
Equipment Status											
Tower Pump "E"	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
Tower Fan	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
Absorption Machine	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
Solar Pumps "A" & "B"	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON/OFF	ON	ON
Hot Water Pumps "1"&"2"	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	ON	ON	ON
Alarm Setting/Status											
Alarm-Low Collector Temperature	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
Alarm-Solar System Leak	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Building											
Thermostat Settings-°F	70	70	75	75	75	70	75	75	75	75	75
Chilled Water Return Temperature -°F	45	45	45	45	N/A	45	45	47	N/A	N/A	N/A
Building Cold Water Pump	ON	ON	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF

NOTES:
a. CAUTION - review collector manufacturer filling and safety precaution prior to filling and testing.
b. See Table 3 for applicable test condition comments prior to initiating the test.
c. T - through; B.P. - Bypass; M -Modulate.

TABLE 3

TEST CONDITON COMMENTS

Test Condition 1

This is a static condition which can also be used to conduct the system pressure tests, after filling, to demonstrate the integrity and safety of the system.

Test Condition 2

This condition is only used to demonstrate the leak detection system. In the drained configuration the flow alarm switch must be manually activated. In the filled configuration a manual drain valve must be opened, simulating a system leak, to activate the flow alarm switch.

Note: System leaks in actual operation should be isolated and repaired, with caution, as soon as possible. Review maintenance and safety precautions recommended by the collector manufacturer.

Test Condition 3

In this test the adjustable control timer must be set to run the Solar Pumps "A" and "B" a minimum of one-half hour. The following must be performed to complete this test condition.

- Adjust timer beyond the minimum setting.
  Note: Solar Pumps "A" and "B" should be "ON".
- Reset T1 to 80°F and T2 to 100°F
  Note: Solar Pumps "A" and "B" should turn "OFF".

Test Condition 4

The following must be performed to complete this test condition.

- Reset T1 to 220°F

  Note: Valve V5 should position for full bypass of the Purge Heat Exchanger.

Test Condition 5

This is a standard solar energy collecting, storing, and building heating mode. There is no requirement for boosting the temperature of the hot water supply to the heating system.

Test Condition 6

This is a standard solar energy collecting, storing, and building cooling mode using the absorption machine. The following must be performed to complete this test condition.

- Reset T1 to 170°F, T2 to 160°F, and T5 to 170°F.

  Notes:
  a. Absorption machine should turn "OFF".
  b. Tower Pump "E" should turn "OFF".
  c. Tower Fan should turn "OFF".
  d. Valve V1 should position for full bypass of the absorption machine.

Test Condition 7

This is a standard building heating mode with no requirement for boosting the temperature of the hot water supply to the heating system.

Test Condition 8

This is a standard building heating mode in which the return hot water from the heating system bypasses the storage tank. The temperature of the hot water supply to the heating system is boosted in the boiler to achieve the desired supply temperature, T4.

Test Condition 9

This is a standard building heating mode as indicated in Test Condition 8. In addition, because of the low outside air temperature, TO, the Solar Pumps "A" and "B" should cycle "ON" for one-half hour every four hours. This operation should be checked by manually advancing the timer through at least two complete cycles.

Test Condition 10

This is a standard building heating mode as indicated in Test Condition 8. In addition, because of the low outside air temperature, TO, and low collector discharge temperature, T1, the water is continuously circulated through the storage tank until T1 exceeds 60°F. Therefore, the following must be performed to complete this test condition.

- Reset T1 to 63°F.

  Notes: a. Solar Pumps "A" and "B" should turn "OFF".

  b. Valve V4 should position for full bypass of the storage tank.

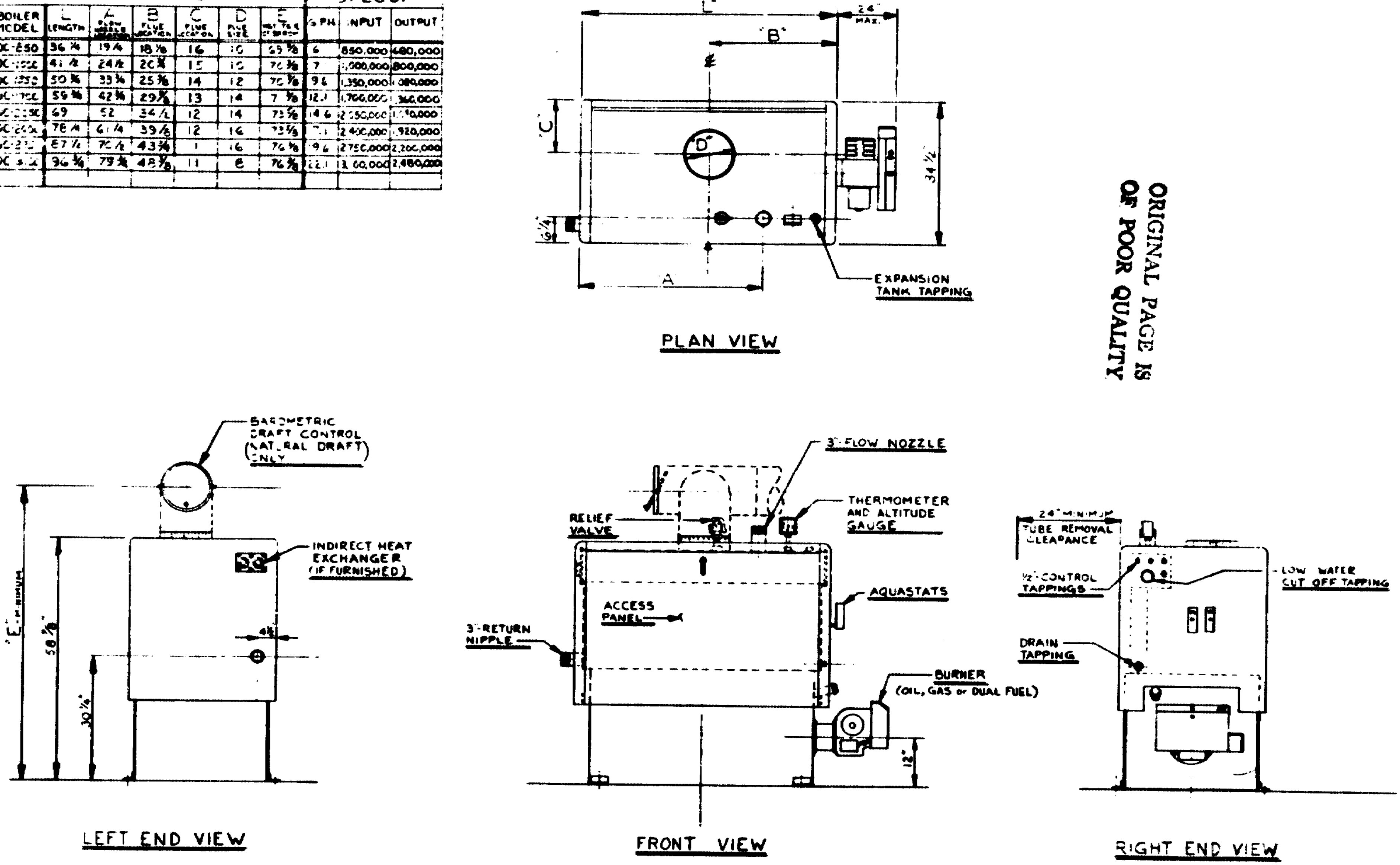
Test Condition 11

This is a standard building heating mode as indicated in Test Condition 8. In addition, because of the low outside air temperature, T0, low collector discharge temperature, T1, and low storage tank temperature, T2, the Low Collector Temperature Alarm should be activated.

Note: If this latter condition occurs in actual operation a manual drain valve must be opened to allow the automatic fill valve to operate and supply city water to the system until this condition is relieved. It should be noted that this action will also activate the Solar System Leak Alarm.

APPENDIX F
VENDOR ITEMS

DIMENSIONS							SPEC's.		
BOILER MODEL	L LENGTH	A FLOW NOZZLE LOCATION	B FLUE LOCATION	C FLUE LOCATION	D FLUE SIZE	E HEIGHT TO CL OF SMOKE	GPH	INPUT	OUTPUT
DC-650	36 ¾	19 ¼	18 ⅛	16	10	69 ⅞	6	850,000	680,000
DC-1000	41 ½	24 ½	20 ⅞	15	10	70 ⅜	7	1,000,000	800,000
DC-1350	50 ⅜	33 ⅜	25 ⅜	14	12	70 ⅞	9.6	1,350,000	1,080,000
DC-1700	59 ⅜	42 ⅜	29 ⅞	13	14	7[illegible] ⅞	12.1	1,700,000	1,360,000
DC-2150	69	52	34 ½	12	14	73 ⅝	14.6	2,150,000	[illegible]
DC-2400	78 ¼	61 ¼	39 ⅛	12	16	73 ⅝	[illegible]	2,400,000	1,920,000
DC-2750	87 ½	70 ½	43 ¾	1[illegible]	16	76 ⅜	19.6	2,750,000	2,200,000
DC-3100	96 ¾	79 ¾	48 ⅞	11	8	76 ⅜	22.1	3,100,000	2,480,000



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DC-SERIES

POWER FIRED BOILERS
OIL, GAS, DUAL GAS-OIL

BRYAN STEAM CORP.

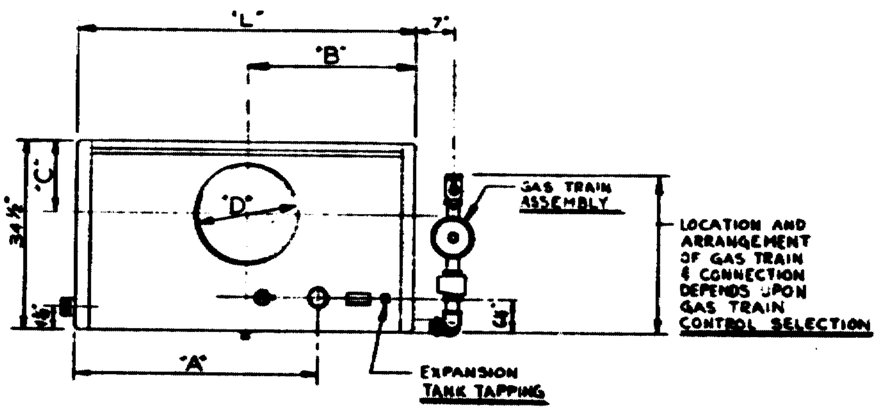
DC-SERIES DIMENSIONAL DRAWING

A | 9-22-[illegible] | CHANGED D-SERIES TO DC-SERIES

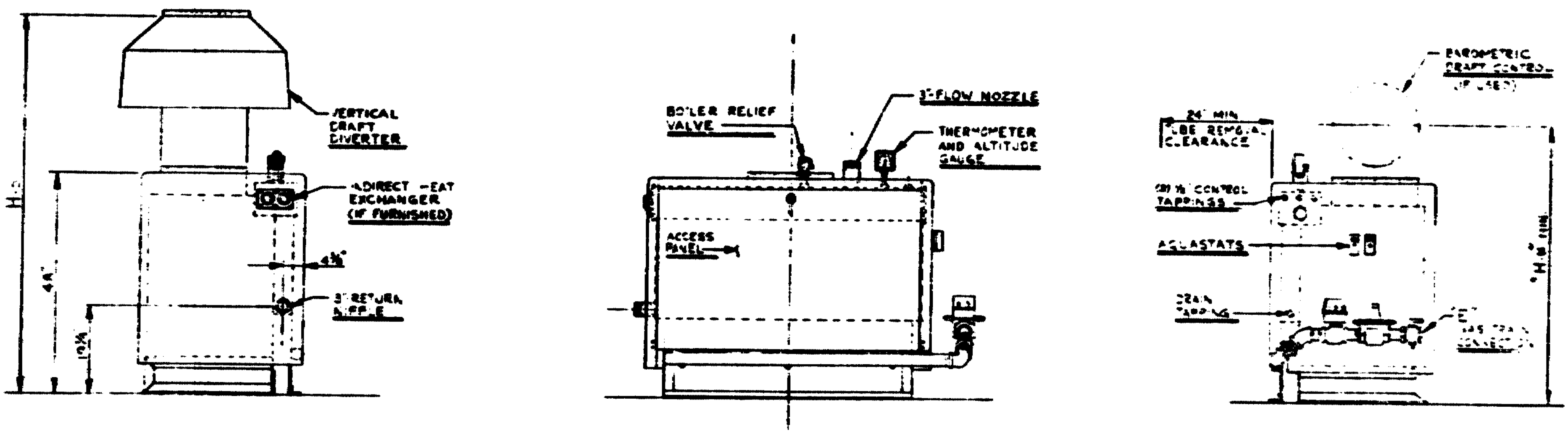
SCALE ¾" = 1'-0"

C-11151-A

DIMENSIONS									SPEC's	
BOILER MODEL	L	H-C	H-B	A	B	C	D	E	INPUT BTU/HR	OUTPUT BTU/HR
FC-800	41½	76⅝	57⅞	24½	20¾	15	14	1¼	900,000	720,000
FC-1200	50⅝	80⅝	59⅝	33⅝	25⅝	14	16	1¼	1,200,000	960,000
FC-1500	59⅝	82⅝	59⅝	42⅝	29⅝	13	18	1½	1,500,000	1,200,000
FC-1800	69	84⅝	60⅝	52	34½	12	20	2	1,800,000	1,440,000
FC-2100	78⅜	84⅝	60⅝	61¼	39⅛	12	20	2	2,100,000	1,680,000
FC-2400	87½	87⅝	61⅝	70½	43⅝	12	22	2½	2,400,000	1,920,000
FC-2700	96⅝	87⅝	61⅝	79⅝	48⅝	12	22	2½	2,700,000	2,160,000
FC-3000	106	89⅝	62⅝	89	53	12	22	2½	3,000,000	2,400,000



PLAN VIEW



LEFT END VIEW

FRONT VIEW

RIGHT END VIEW

FC- SERIES
ATMOSPHERIC - GAS FIRED

BRYAN STEAM CORP.

FC-SERIES DIMENSIONAL DRAWING

C-11158

TRANE ABSORPTION COLD GENERATOR SUBMITTAL DATA

ARCHITECT: MC DONALD, CASSELL & BASSETT

ENGINEER: HEAPY & ASSOC. - DAYTON

PROJECT AND LOCATION: COLUMBUS TECHNICAL INSTITUTE COLUMBUS, OHIO

ORDER DATE	CUSTOMER ORDER NO.	CUSTOMER ACCOUNT NO.
7-15-77	CT-9339	

SOLD TO:
DUCKWORTH PLUMBING CO.
7617 DILEY ROAD
CANAL WINCHESTER, OHIO 43110
ZIP CODE

TAG: ABS ☐ 071 ☐ 171 SHIP WITH:

APPROVAL STAMP

NOT APPROVED BY
HEAPY & ASSOCIATES
BY Larry Smith /DD
DATE 8-31-77

ABS UNIT DATA

ITEM	QTY	MODEL	CAPACITY (TONS)	PURGE MOTOR H.P. 1/4	115/60/1
A	1	ABSC-01A4-WA-8BCE	35	PUMP MOTOR H.P. 5	460 V/60/3
				FLA 8.1	LRA 46

OPERATING CONDITIONS

SECTION		GPM	EW°F	LW°F		PD. FT.	PASSES
EVAPORATOR	L	85	55	45	.0005	20	8
ABSORBER	L	300	85		.0005	22	4
CONDENSER	L						2
CONC (H.W.)	R	70	192	180	.0005	8	4
		BOILER WATER TEMP.			PRESSURE (SHUT-OFF)		
CONC (STM)	R		PSIG TO VALVE			PSIG TO MACHINE	
		#/HR				°F SUPERHEAT	

VALVE

LA CROSSE USE ONLY | % STROKE | DEGREES ROTATION

SUPPLY CAPACITY CONTROL VALVE ____ Cv(1) ____ IN FLANGE
(NOTE — H. W. VALVES ARE SELECTED ON 10 PSI DROP (2) ____ IN FLANGE
UNLESS STATED OTHERWISE.)

OPTIONS

	SINGLE-STAGE	TWO-STAGE
ECONOMIZER	WITH ☒	
DEMAND LIMITER	WITH ☒	WITH ☐
FLANGED WATER CONNECTIONS	WITH ☐	WITH ☐
STEAM START-UP STABILIZER	WITH ☐	
POSITIVE CONCENTRATION LIMIT	WITH ☒	WITH ☐
CONDENSATE HEAT EXCHANGER		WITH ☐
SHIPPING CONFIGURATION		☐ ASSEMBLED ☐ DISASSEMBLED
STEAM PRESSURE UNIT		☐ 144 PSIG ☐ 122 PSIG
DUAL UNIT OPERATION	☐ SERIES ☐ PARALLEL	☐ SEPARATE

SPECIAL FEATURES

HOT WATER VALUE BY T.C. CONTRACTOR

SUBMITTAL DATA TO BE COMPLETED BY LA CROSSE

BLUELINE ASSY. ABSC-S-22 — 1 DRUMS OF LiBr-1
WIRING E2304-1098 — 6 DRUMS OF LiBr-2
PIPING ABSC-S-45 — DRUMS OF LiBr-3
PIPING COMBINATION 32
CONTROL VALVE BY OTHERS

TRANE ABSORPTION COLD GENERATORS INCORPORATE THESE ADVANCED FEATURES:

1. ABILITY TO START AND OPERATE WITH COOLING WATER TEMPERATURE AS LOW AS 55° F
2. UNMATCHED PUMP AND MOTOR SERVICEABILITY
3. REFRIGERANT COOLED, HERMETIC PUMP — ONLY ONE MOVING PART
4. FIXED AND FLOATING CONCENTRATOR SUPPORTS
5. CUNI CONCENTRATOR AND ABSORBER TUBING

1. Provide full range modulating economizer
2. Absorber, concentrator, evaporator + condenser to have cupronickel tubes
3. Provide signed service agreement
4. Contractor must stamp submittal with his approval stamp

CHECKED AND APPROVED FOR SUBMISSION TO THE ARCHITECT
RD
DUCKWORTH PLUMBING CO.
DATE

TP
MBH 13 COLUMBUS SNYDER

SALES ORDER NUMBER N4-E406

SHEET 1 OF 1

SUBMITTAL DATA

1-30.272-4 — (1175)

THE TRANE COMPANY, LA CROSSE, WISCONSIN

TRANE AIR CONDITIONING

SUBMITTAL

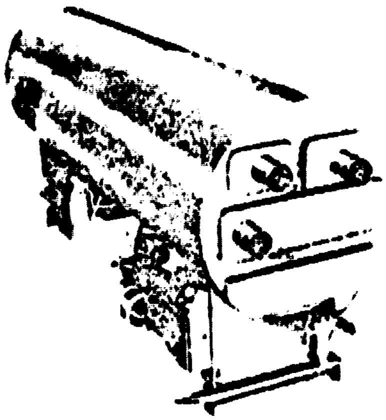
FILE:
TRANE REFRIGERATION PRODUCTS
LIQUID CHILLERS-ABSORPTION
Cold Generator
Model C
Submittal

ABSC-S-45

FEBRUARY, 1976

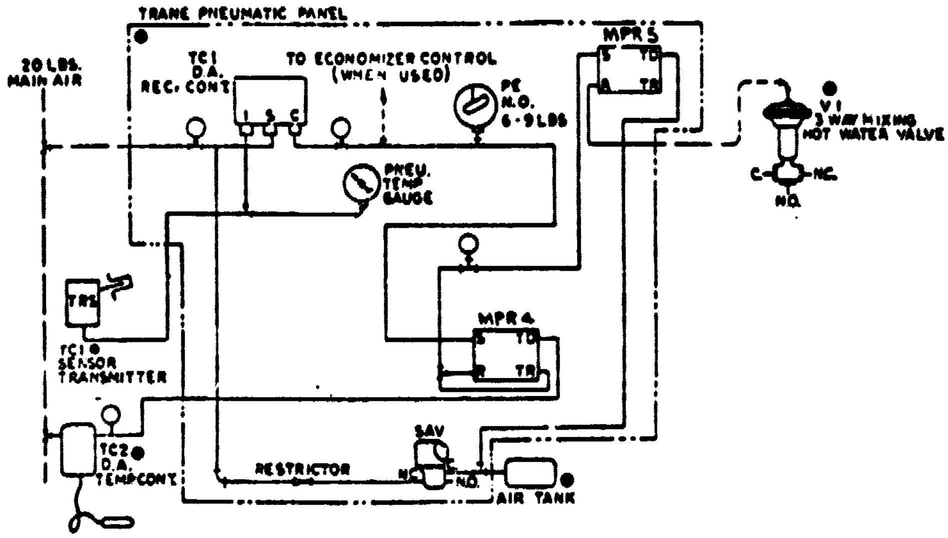
THE TRANE COMPANY — LA CROSSE, WISCONSIN 54601

COMMERCIAL AIR CONDITIONING DIVISION



ABSORPTION COLD GENERATORS™
MEDIUM TEMPERATURE
HOT WATER
MODEL ABSC

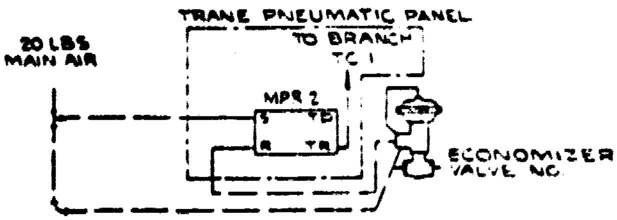
PIPING AND PNEUMATIC CONTROL



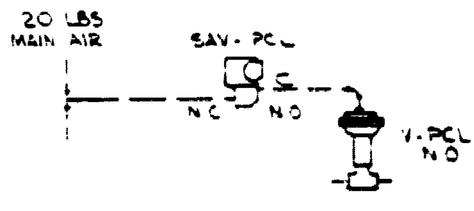
PNEUMATIC DIAGRAM FOR STANDARD CONTROL
INCLUDING DEMAND LIMITER

TC1 - DIRECT ACTING RECEIVER/CONTROLLER
TC2 - DIRECT ACTING TEMPERATURE CONTROLLER
TRS - TEMPERATURE SENSOR - TRANSMITTER
SAV1 - SOLENOID AIR VALVE
PE - PNEUMATIC ELECTRIC SWITCH
MPR5 - MULTI-PURPOSE RELAY (LOW PRESSURE SELECTOR)
MPR2 - REVERSING MULTI-PURPOSE RELAY
MPR6 - MULTI-PURPOSE RELAY (CHARACTERIZED MINIMUM PRESSURE - LOW PRESSURE SELECTOR)

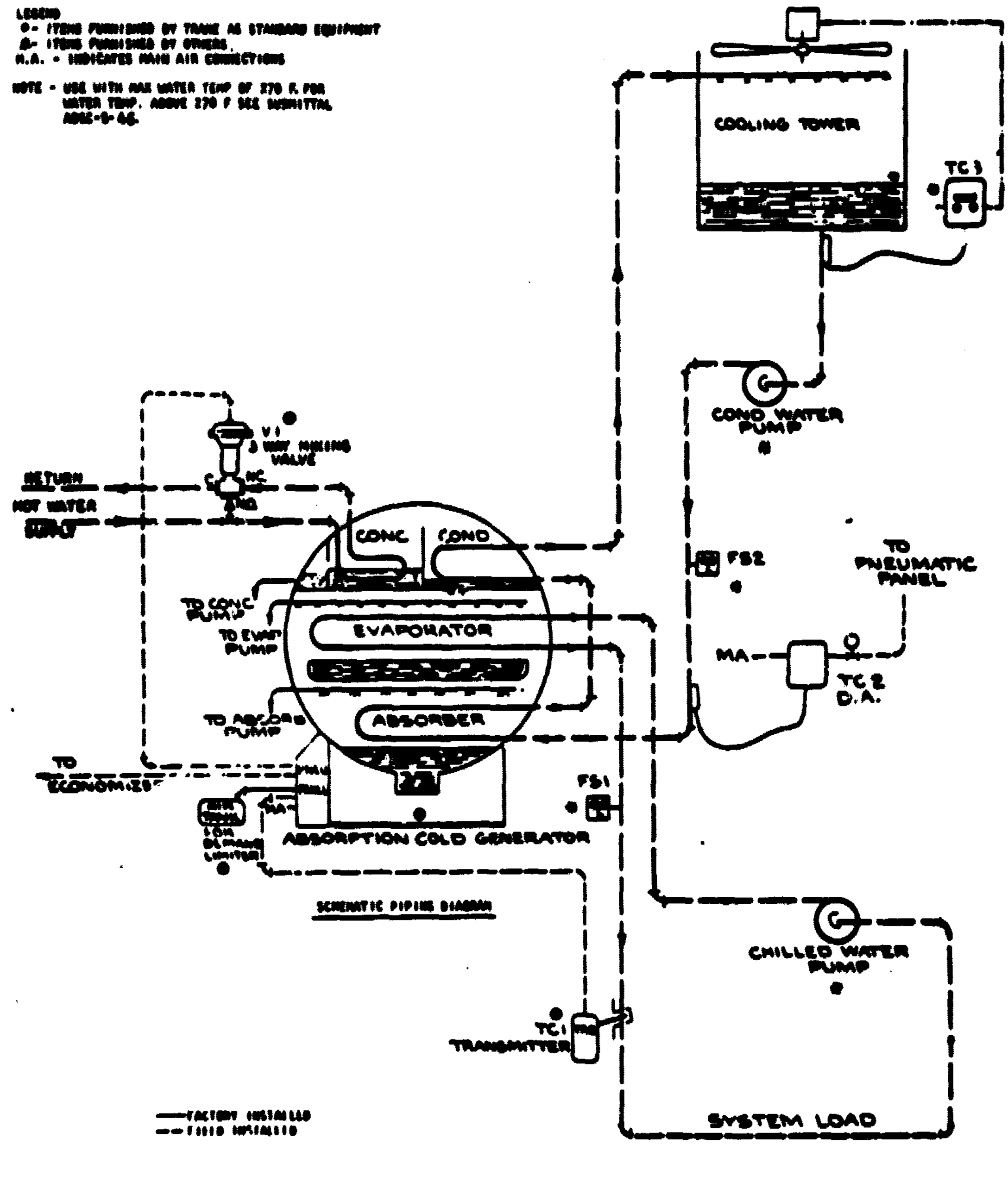
—— FACTORY INSTALLED
– – FIELD INSTALLED



PNEU. DIAG. FOR ADDED ECONOMIZER CONTROL



PNEU. DIAG. FOR ADDED V-PCL CONTROL



SCHEMATIC PIPING DIAGRAM

1602-0216C

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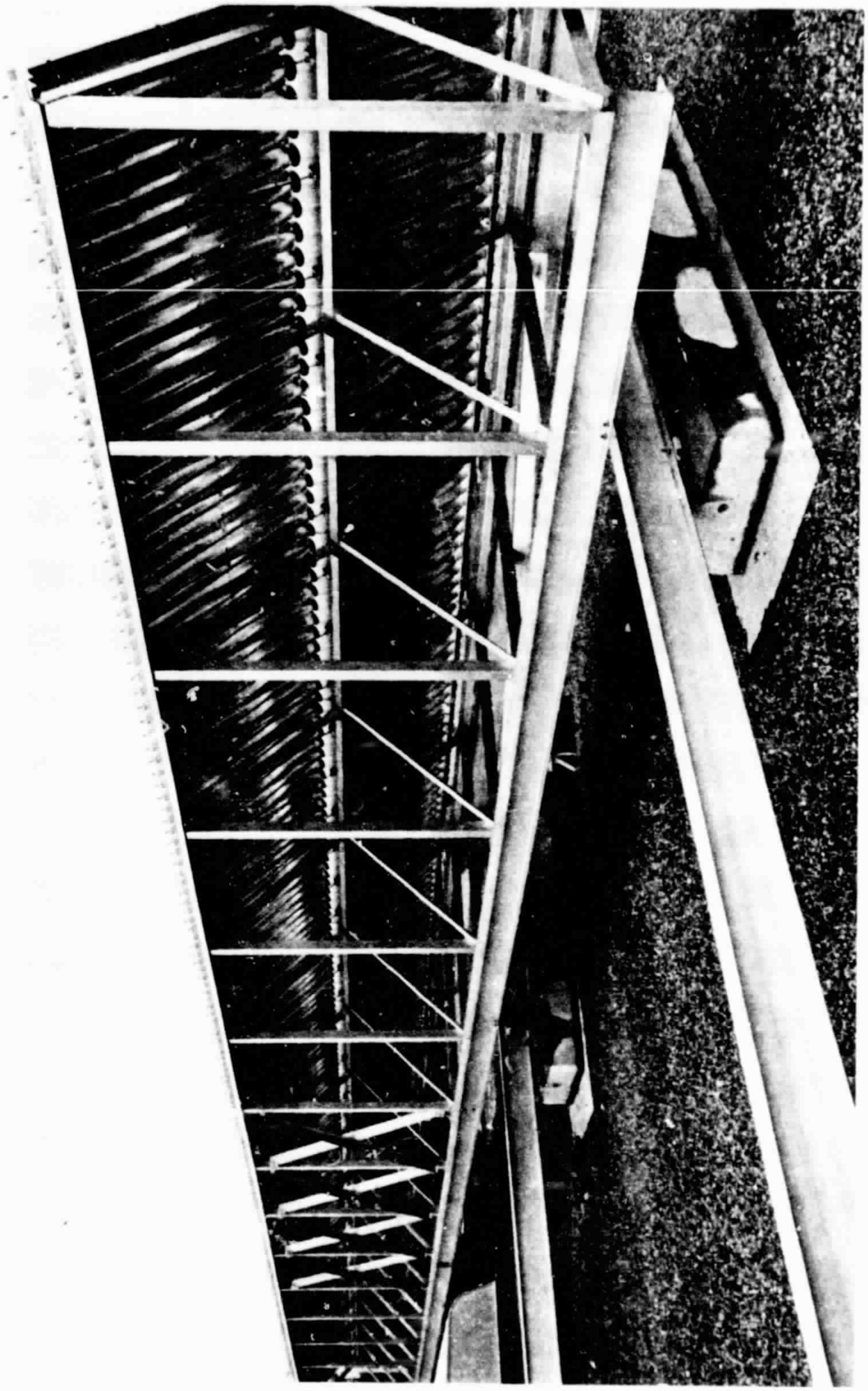
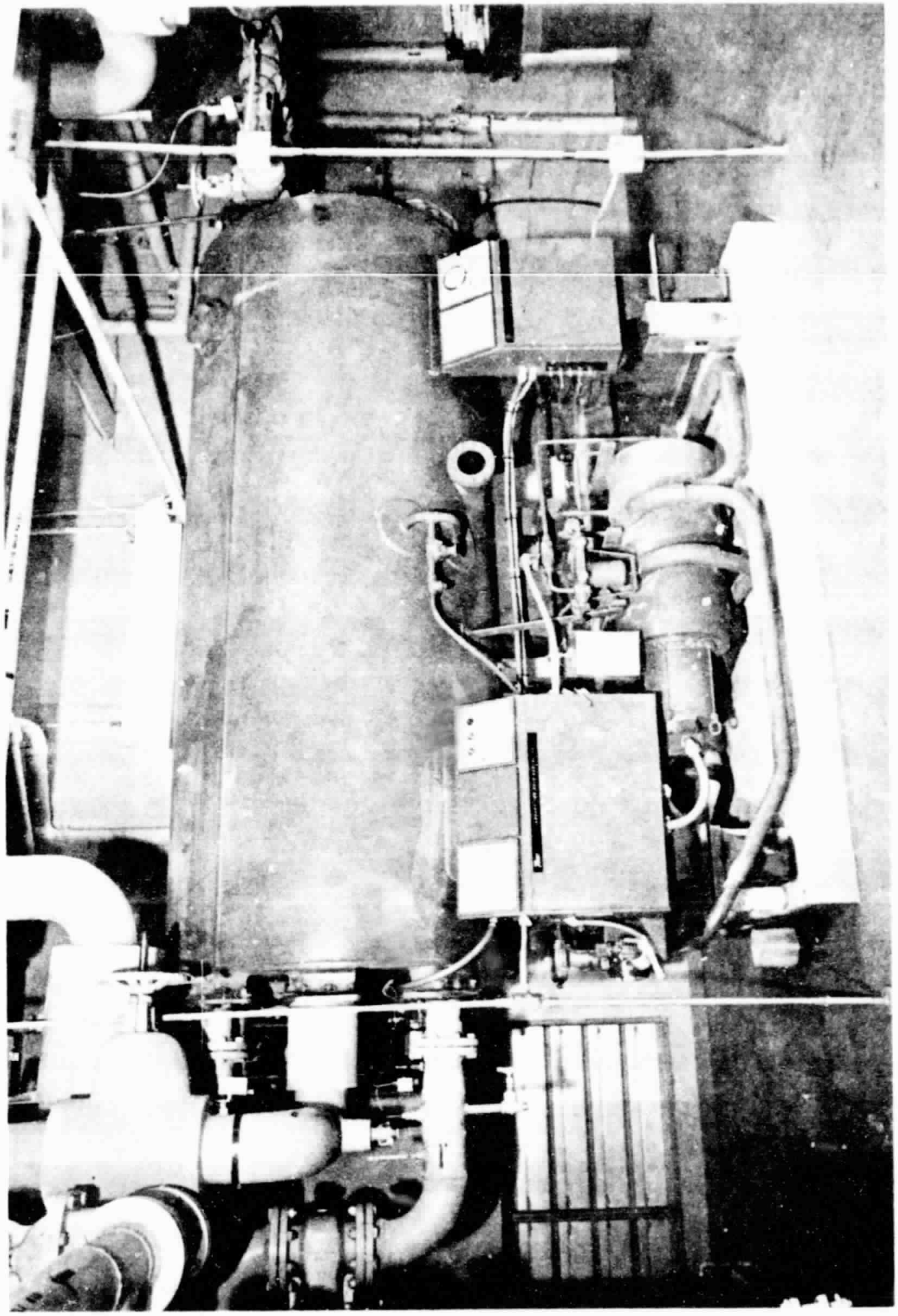
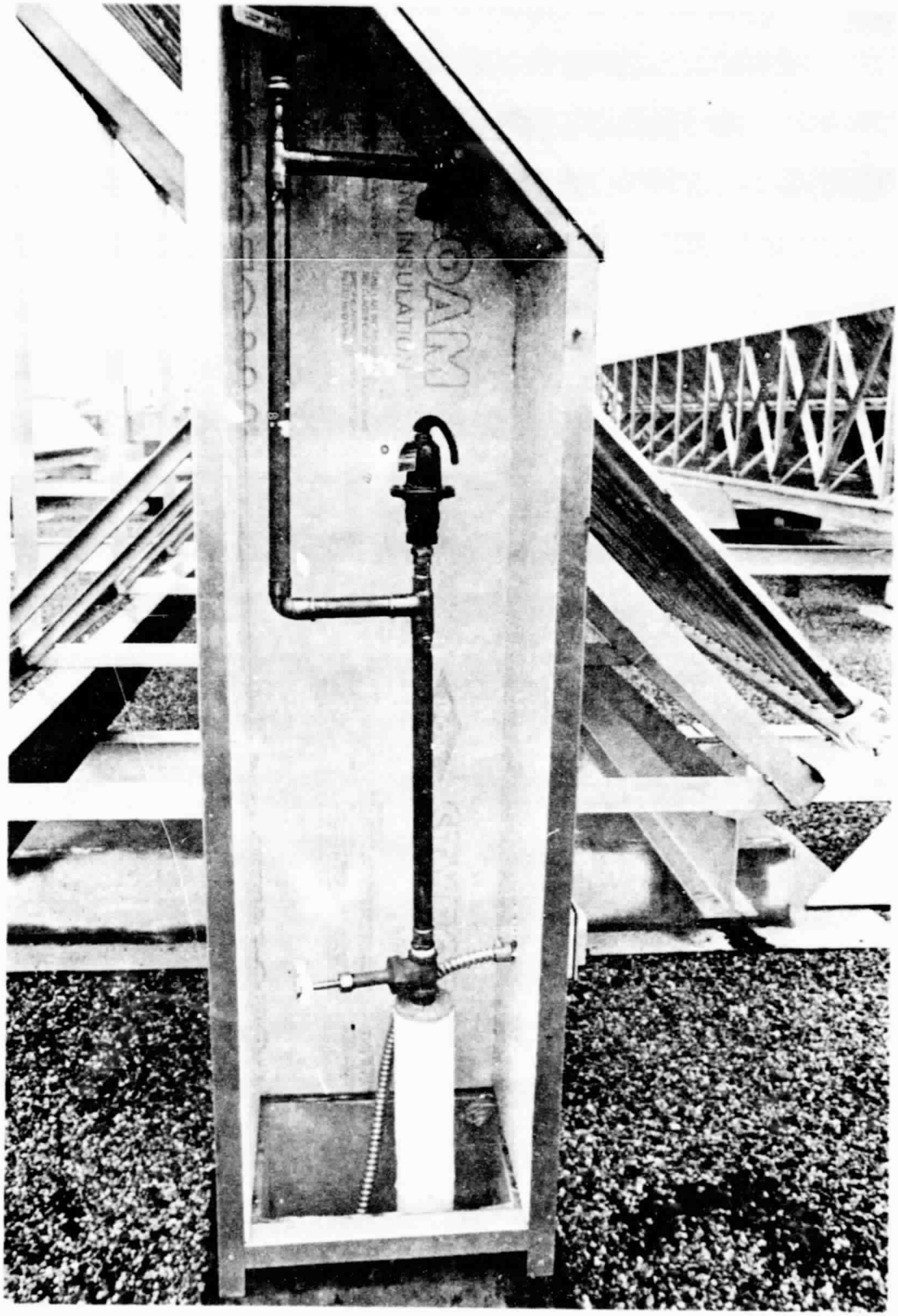
Solar Collectors with Roof Curbs.



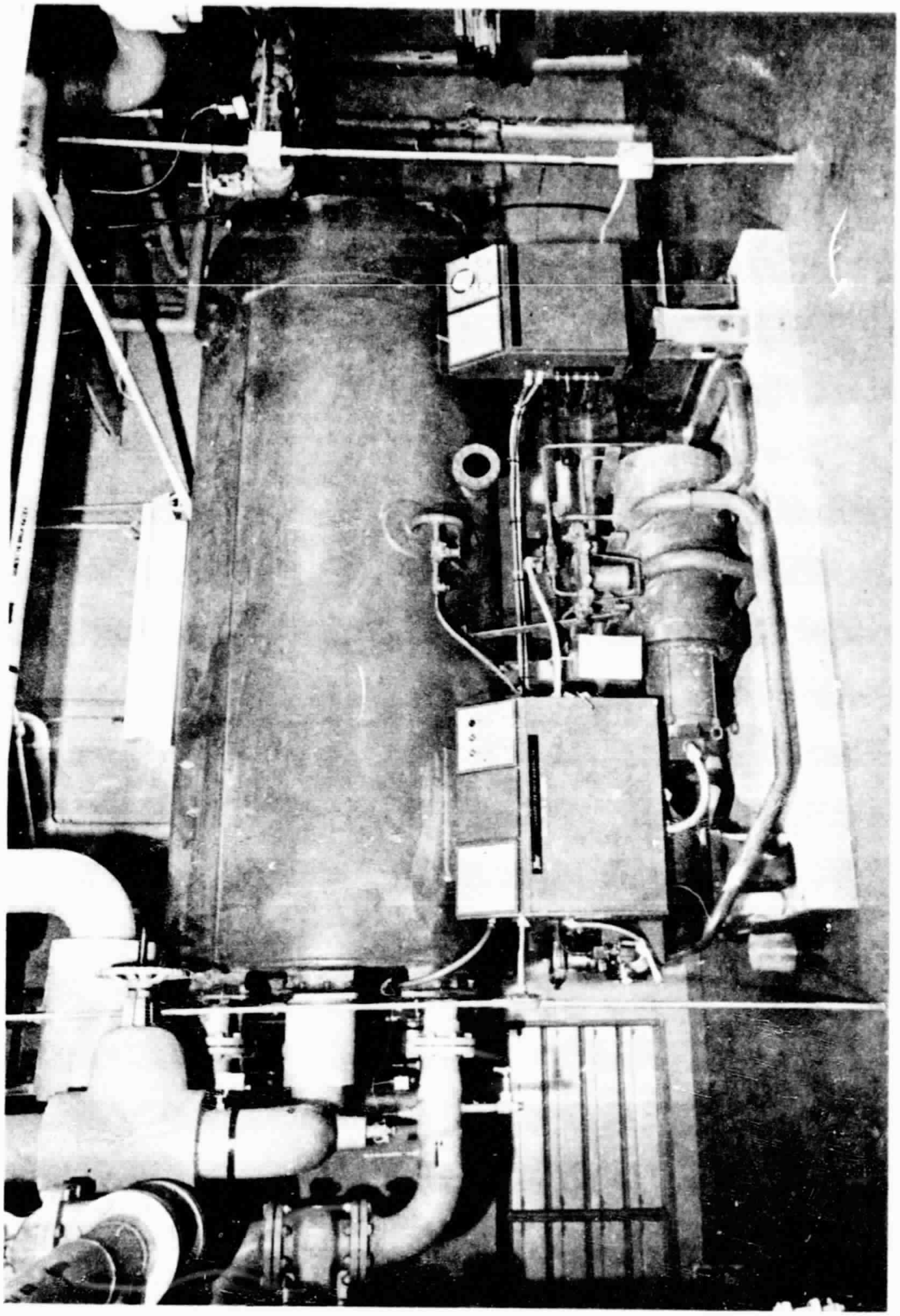
Solar Collector Structural Framework.



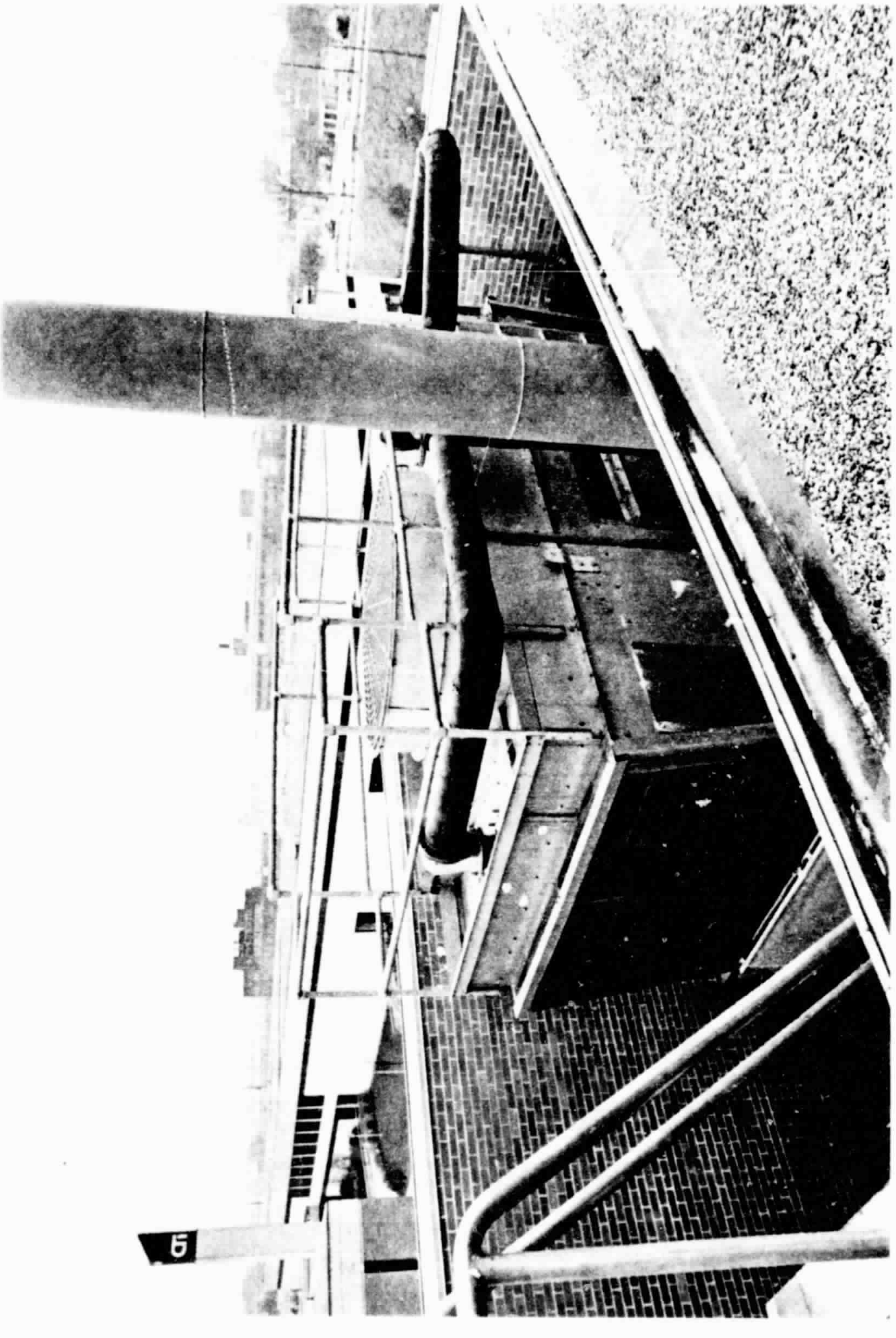
Absorption Chiller.



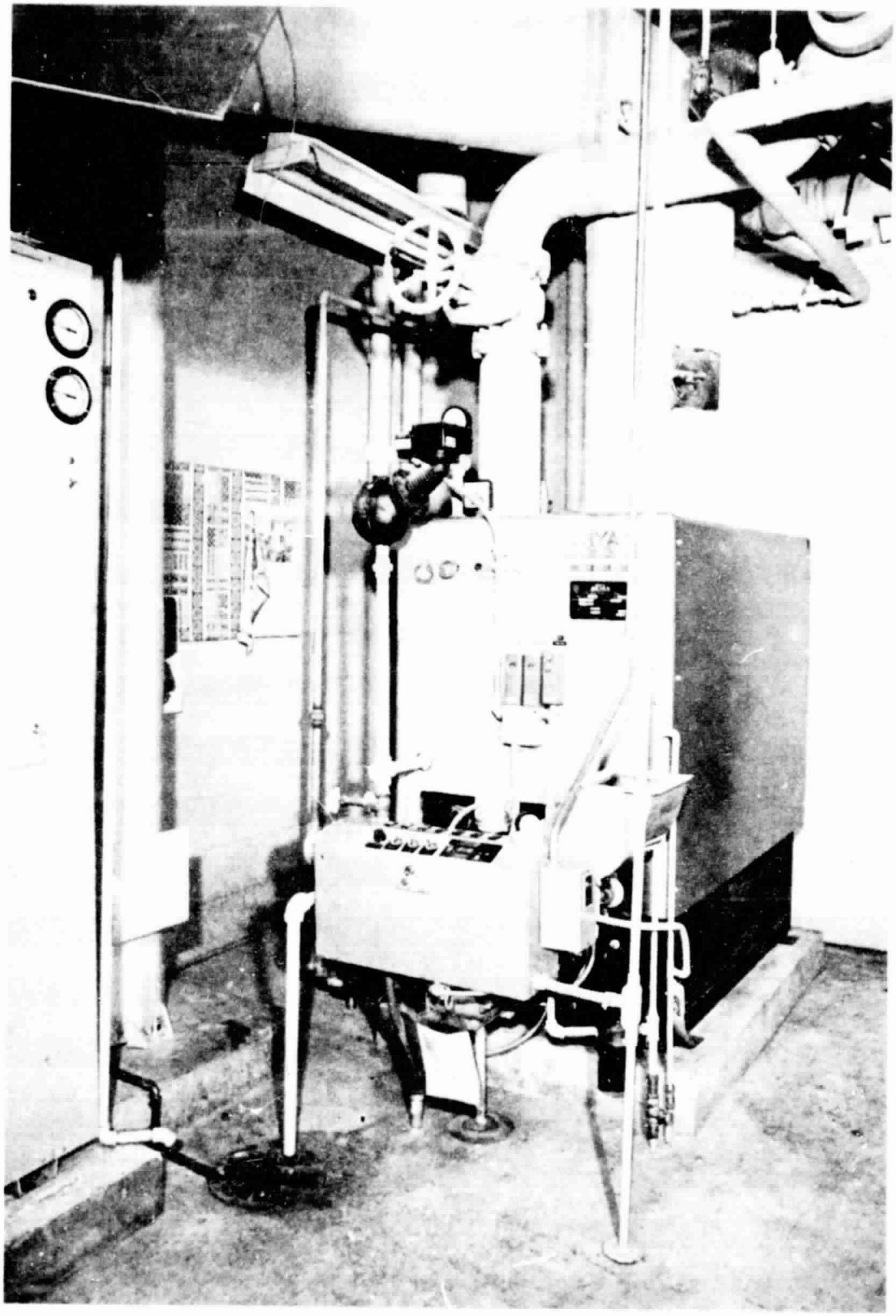
Details of Roof Curb.



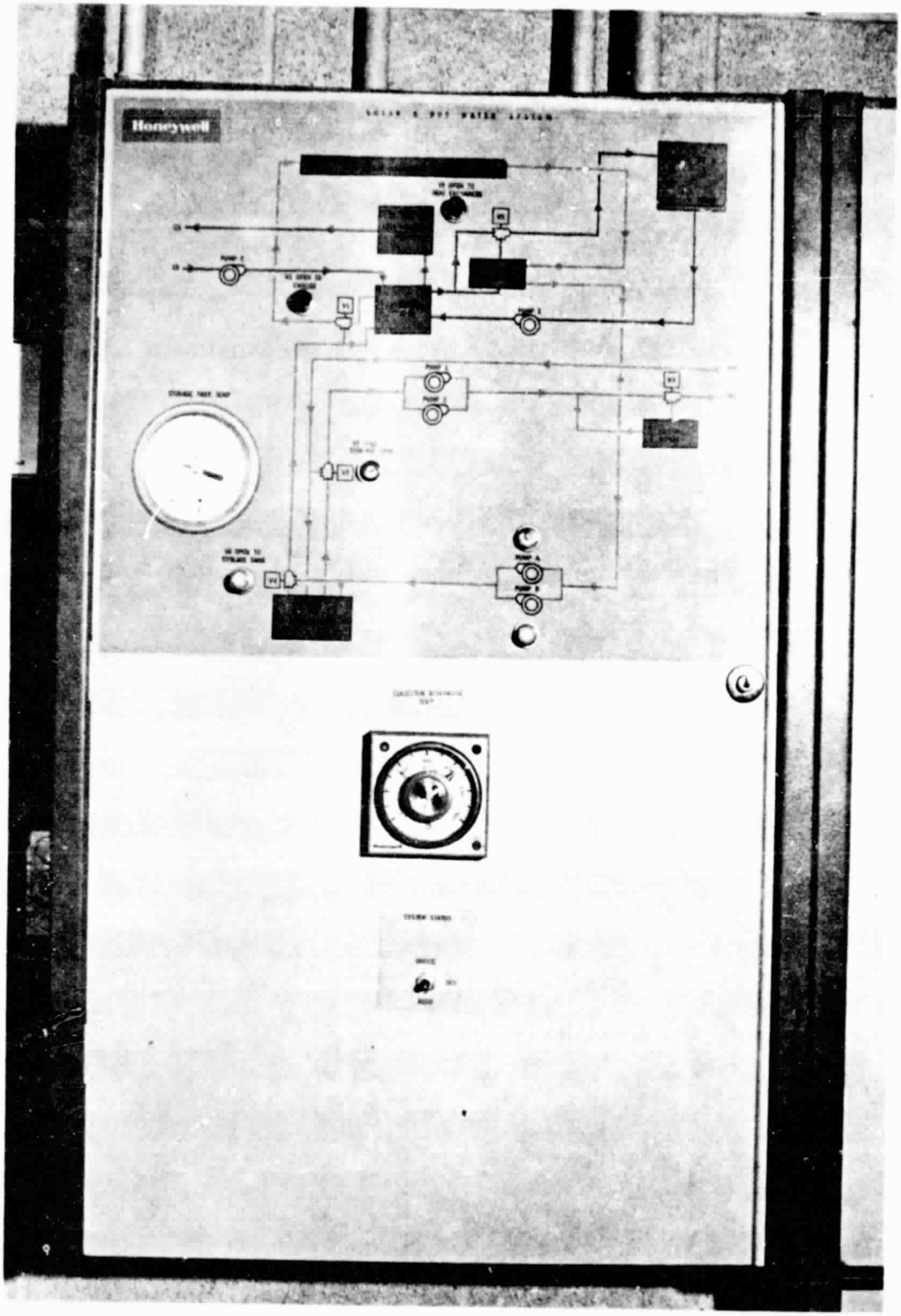
Absorption Chiller.



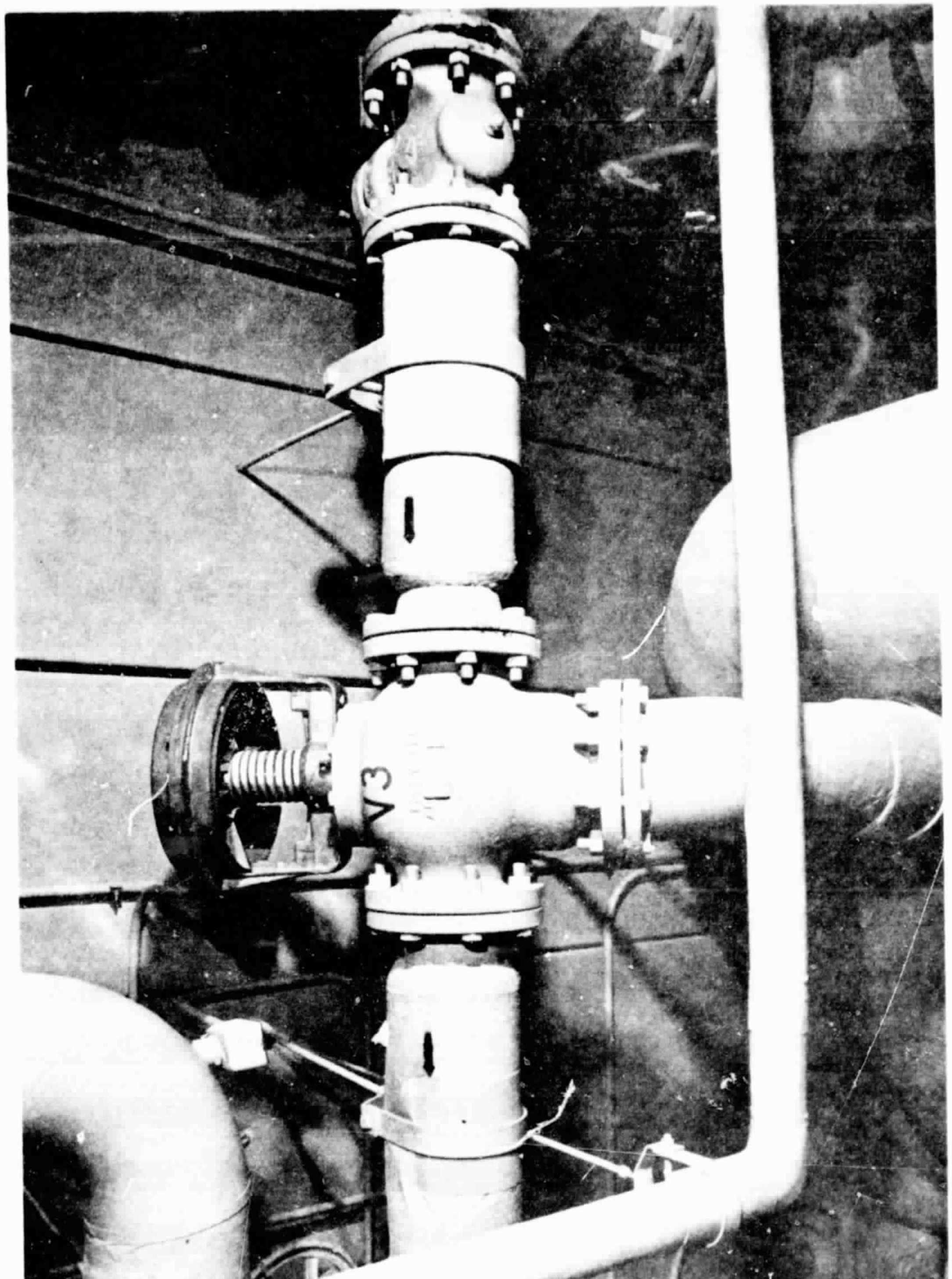
Cooling Tower.



Gas/Fuel Oil Boiler.



Solar Control Panel.



Typical Pneumatic Three-Way Valve.